DOCUMENT RESUME

ED 201 217 HE 013 066

TITLE	Industry and the Universities: Developing Cooperative Research Relationships in the National Interest.
INSTITUTION	National Commission on Research, Washington, D.C.
SPONS AGENCY	Carnegie Corp. of New York, N.Y.; EXXON Education Foundation, New York, N.Y.
PUB DATE	Aug 80
NOTE	49p.
AVAILABLE FROM	National Commission on Research, 337-32, California Institute of Technology, Pasadena, CA 91125.
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	College Role: *Cooperative Programs; *Government Role; Higher Education; *Industry; Institutional Role; Research; Researchers; Research Needs; *Research Projects; *School Business Relationship; Trend Analysis; *Universities
IDENTIFIERS	*Research Universities

ABSTRACT

Benefits to the nation as well as problems involved in cooperative research relationships between industry and universities are considered. The background and history of the relationship between universities and industry, including the changing roles and objectives of the participants, are covered. Trends in the support and performance of basic research between the 1950s and the present are summarized. These trends show the increased role of government and the shift of expenditures by industry from basic research to applied research and development. The consequences of lack of research cooperation between universities and industry are noted. The relationship between universities, industry, and government is defined through consideration of fundamental principles that guide their actions, the benefits and hazards to each participant arising from the cooperative research relationship, and the roles and responsibilities of each participant. Selected alternatives for university-industry research relationship, including recent new initiatives, are described. Government financial incentives for industrial support of university research are also considered. (SW)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED201217

INDUSTRY AND THE UNIVERSITIES:

Developing Cooperative Research Relationships in the National Interest

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
National Commission on Research
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

HE 013 066

National Commission on Research

National Commission on Research

WILLIAM D. CAREY
Executive Director
American Association for the Advancement of Science

PHILIP P. COHEN
Professor Emeritus
Department of Physiological Chemistry
University of Wisconsin Medical Center, Madison

DALE R. CORSON
President Emeritus
Cornell University

EDWARD E. DAVID, JR.
President
Exxon Research and Engineering Company

CARL KAYSEN (Consulting Member)
Vice Chairman and Director for Research
The Sloan Commission on Government and Higher Education

DONALD N. LANGENBERG
Professor of Physics
University of Pennsylvania

IRWIN C. LIEB
Professor of Philosophy
University of Texas, Austin

CHARLES A. MOSHER
Fellow
Woodrow Wilson International Center for Scholars

RAYMOND L. ORBACH
Professor of Physics
University of California, Los Angeles

CORNELIUS J. PINGS (Director)
Vice Provost and Dean of Graduate Studies
California Institute of Technology

WILLIAM H. SEWELL (Chairman)
Professor of Sociology
University of Wisconsin, Madison

MONTE C. THRODAHL
Senior Vice President
Monsanto Company

LINDA S. WILSON
Associate Vice Chancellor for Research
University of Illinois, Urbana

Staff

GREGORY FUSCO, Executive Director
CYNTHIA P. KING, Staff Associate
MARYANN M. KOWALCZYK, Staff Assistant

NATIONAL COMMISSION ON RESEARCH

Industry and the Universities: Developing Cooperative Research Relationships in the National Interest

Executive Summary

The theme of this report holds that improved university-industry cooperative research can produce significant benefits for the nation. It is in the government's interest to facilitate the relationship. Difficulties arise because of the very different character of the institutions and the responsibilities of the participants.

The Commission

The National Commission on Research was formed in late 1978 as an independent body. It was sponsored by interested organizations and supported principally by private foundations. The Commission was charged to study the relationship between the government and the research universities, to determine the nature and origins of the problems afflicting the relationship, and to recommend ways to solve these problems. Additional information on the origins and purposes of the Commission is contained in the Foreword (p. ix).

University-Industry Cooperative Research

Universities and technologically oriented companies function in different worlds. Yet there are many societal needs with dimensions exceeding the capabilities or scope of either universities or industry. The Commission recommends in this document that it is time to explore new ways for these two segments of society to produce synergistic results through programs of cooperative research.

The Introduction (p. 1) presents the opportunities which can develop from cooperative research relationships, while noting the very different roles of each of the participants. The section on background and history of the relationship between universities and industry (p. 3) begins with a discussion of the changing roles and objectives of the participants, placing research in the context of the innovation process. Trends in the support and performance of basic research between the 1950s and the present are displayed and summarized. These exhibit the increased role of government and the shift of expenditures by industry from basic research to applied research and development, although the level of funding for basic research by industry has risen in absolute terms. The consequences of lack of research cooperation between universities and industry are inefficient and unproductive dissemination of research results, and a lack of feedback from industry to universities concerning societal problems to the solution of which basic research could make relevant contributions. The relationship between universities, industry, and government is defined in the next section (p. 13) by first stating the fundamental principles which the Commission believes guides their actions; the benefits and hazards to each participant arising from the university-industry cooperative research relationship; and finally the roles and responsibilities of each participant requisite for the success of cooperative research programs. Selected alternatives for university-industry research relationships, including recent new initiatives, are described in the next section (p. 19). This section concludes with a discussion of government financial incentives for industrial support of university research.

Conclusions

The Commission reviewed the state of research and innovation in the United States. It also considered the variety of needs and philosophies that guide the actions of universities, industry, and the government. In light

TEAR SHEET—EXECUTIVE SUMMARY REPEATED ON PAGE xi.

of these factors, the Commission concludes that university-industry cooperative research relationships are beneficial and should be encouraged. More specifically, this report offers the following conclusions:

1. The ultimate result of any form of university-industry research relationship must be better products and services useful to the public.
2. Universities house the greater volume of basic research activity and are likely to continue to do so.
3. Research relationships between industry and universities can strengthen the innovation process and improve the vigor of research within the universities.
4. A close working relationship between the university researcher and the industrial counterpart is an imperative for a strong university-industry cooperative research program.
5. University-industry research relationships can contribute significantly to university research and instructional resources.
6. Equitable financial rewards should accrue to industry and to universities from explicit research relationships.
7. Hazards to university academic freedom from university-industry research relationships are manageable.
8. Universities, in seeking opportunities for cooperative research with industry, must exercise care to avoid subversion of proper university purposes.
9. Government can encourage and support the university-industry research relationship by becoming a facilitator rather than an ongoing participant in direction or management.
10. The less basic the research, the more difficult becomes the determination of whether the use of public funds for university-industry research relationships is proper.
11. The public must be informed of the nature and rationale of specific university-industry research relationships.
12. Misunderstanding and mistrust exist among members of industry, university students and faculty, and the general public, impeding cooperative research relationships between industry and universities. A new mechanism for discussion and resolution of the issues is needed.

Recommendations

An explanation of each recommendation is contained in the full report (p. 29). Recommendation 1 defines the character of the cooperative research relationship and is directed to all the participants. Recommendation 2 is directed at industry and suggests a mechanism for companies with common research interests. Recommendations 3 through 5 are directed to the Federal government and are mechanisms for facilitating the development of cooperative research relationships. Recommendation 6 deals with basic research relevant to regulatory policy. Recommendation 7 is directed to universities and outlines structural features which must be developed for administration of cooperative research relationships. Recommendations 8 and 9 are directed to both universities and industry and focus on public understanding of the cooperative research relationship.

1. The Commission recommends that research universities and industry explore effective cooperative research relationships which:

   a. Are designed around important scientific areas of mutual interest, individually tailored to the characteristics of each participant—emphasizing investigator-to-investigator interaction;

   b. Possess clearly stated objectives that preserve each partner's purposes and policies, recognizing that the often subtle differences fundamental to each partner must be understood and respected;

   c. Allow the individual researchers from both universities and industry to determine the specific choice of subjects to be investigated. Permit each partner's participants to share in any phase of the projects appropriate to their skills;

   d. Provide for financial reward to industry and to the university for assuming the risks of bringing highly uncertain scientific and technological programs to fruition and usefulness;

   e. Provide opportunities for demonstrating research performance and ethical qualities that will develop mutual respect for doing good science; and

   f. Develop a commitment for long-range support of research recognizing that meaningful research results are rarely achieved in short periods of time.

2. The Commission recommends that companies within a sector of industry review their research needs and explore the possibility of combining their resources for the support of a coordinated program of cooperative research with universities.

3. The Commission recommends that the Federal government encourage the application of research results to product development by permitting universities to retain title to inventions developed under federally supported research.
4. The Commission recommends that the Federal government provide financial incentives to initiate and maintain closer research ties between industry and universities. Tax policy provides an effective vehicle for such incentives.
5. The Commission recommends continued direct university-industry cooperative research relationships based on models which have proven effective. One such example is the National Science Foundation Industrial-University Cooperative Research Project Program.
6. The Commission recommends that university researchers be encouraged to contribute to the research knowledge base required for regulatory policy, particularly in the biological/environmental area.
7. The Commission recommends that universities examine their administrative structures and policies relevant to cooperative research arrangements with industry. Such research arrangements should facilitate cooperation, while protecting the academic research environment. Universities also should examine their patent policies and be sure they have staff capable of identifying and pursuing patent opportunities.
8. The Commission recommends that universities and industry take steps toward removing the misunderstanding and mistrust between them.
9. The Commission recommends that universities and industry inform the public of the rationale for their participation in cooperative research programs. They must make public the developing relationships and the outcome of cooperative research programs.

INDUSTRY AND THE UNIVERSITIES:

Developing Cooperative Research Relationships in the National Interest

National Commission on Research
August 1980

Permission is hereby granted to any nonprofit organization or institution to reprint this document provided that:

1. Each copy of the reprint carries a notice stating, "Reprinted from *Industry and the Universities: Developing Cooperative Research Relationships in the National Interest* by permission of the National Commission on Research, c/o Dr. Cornelius J. Pings, 337-32, California Institute of Technology, Pasadena, California 91125. Single copies of the original document are available free of charge on request to the Commission."

2. A copy of the reprint is sent to the Commission with a statement that identifies the agency making the reprint, gives the date of the reprint, reports the number of copies reprinted, and outlines how and to whom the reprints are being distributed.

Copies of this document, as well as other volumes in this series of reports on the relationship between the research universities and the Federal government, may be ordered from the National Commission on Research, c/o Dr. Cornelius J. Pings, 337-32, California Institute of Technology, Pasadena, California 91125. Single copies of each document are free.

Copyright 1980 by National Commission on Research.
All rights reserved.

Printed in the United States of America.

Table of Contents

LIST OF FIGURES, CHARTS, AND TABLES viii

FOREWORD ix

EXECUTIVE SUMMARY xi

INTRODUCTION 1

BACKGROUND AND HISTORY 3
- Changing Roles and Objectives of Participants, 3
- Trends in Basic Research Performance and Support, 1953-1978, 4
- Consequences, 11
  - Dissemination of Research Results, 11
  - Lack of Feedback from Industry to Universities Concerning Societal Problems, 11

DEFINING THE RELATIONSHIP 13
- Fundamental Principles of the Participants, 13
  - Fundamental Principles for the Research Universities, 13
  - Fundamental Principles for Industry, 14
  - Fundamental Principles for the Federal Government, 14
- Benefits and Hazards of the Relationship, 15
  - Benefits to the University and the University Researcher, 15
  - Benefits to Industry, 15
  - Benefits to the Government and the Public Interest, 17
  - Hazards to the University, 17
  - Hazards to Industry, 17
  - Hazards to Government and the Public Interest, 17
- Roles and Responsibilities of the Partners, 17
  - Roles and Responsibilities of the University, 17
  - Roles and Responsibilities of Industry, 18
  - Roles and Responsibilities of Government, 18

SELECTED ALTERNATIVES FOR UNIVERSITY-INDUSTRY RESEARCH RELATIONSHIPS 19
- Characteristics of Alternatives, 19
- Alternatives, 20

CONCLUSIONS 25

RECOMMENDATIONS 29

APPENDIX I: REFERENCES 33

APPENDIX II: BIBLIOGRAPHY 35

APPENDIX III: SOURCES 37

List of Figures, Charts, and Tables

Figures

1: Organization Involvement in the Innovation Process 5

2: University and Industry Research and Development Spending Patterns 6

3: Funds Expended Annually for Performance of Basic Research by Universities and Colleges (current dollars) 10

4: Funds Expended Annually for Performance of Basic Research by Universities and Colleges (constant 1972 dollars) 10

Charts

Expenditures by Performer 8-9

Tables

1: Total Expenditures for Basic Research 6

2: Ratios of Increased Expenditures 7

3: Benefits . . . Hazards . . . Roles and Responsibilities 16

Foreword

The National Commission on Research is a private, nonprofit organization established to examine the relationships between government agencies and universities involved in research and to develop specific recommendations for improvements. The Commission was founded in the latter half of 1978 by the American Council on Education, the American Council of Learned Societies, the Association of American Universities, the National Academy of Sciences, the National Association of State Universities and Land-Grant Colleges, and the Social Science Research Council. The Commission works independently of its founders to examine the process by which the Federal government supports academic research and to propose changes designed to improve that process.

Funding has been obtained for Commission activities to pursue this task from the following organizations: Carnegie Corporation of New York, Exxon Education Foundation, Ford Foundation, the William and Flora Hewlett Foundation, the Andrew W. Mellon Foundation, the National Science Foundation (Grants Nos. PRM-7903778 and CDP-7926386), the U.S. Department of Energy (Grant No. DE-FG01-80ER10167), and the Air Force Office of Scientific Research (Grant No. AFOSR-ISSA-80-00030). Over three-fourths of the funding was made available by the five private agencies and approximately one-fourth from the public sources. Any opinions, findings, conclusions, and recommendations expressed in this publication are the sole responsibility of the Commission and do not necessarily reflect the views of any of the aforementioned funding sources or founders.

This publication on university-industry cooperative research relationships is the fourth in a series of documents developed by the Commission to analyze the process of government funding and university involvement in research and to make recommendations to all affected parties for improvements in the system. Subcommittees of the Commission have investigated each of the following issues:

(1) Accountability;
(2) Peer review and other selection processes;
(3) Alternative funding mechanisms;
(4) Industry/university/government relationships; and
(5) Development of research personnel.

Position papers on each of the first three topics have been published by the Commission. An essay on research personnel will be released at the same time as this document.

Members of the Subcommittee on Industry/University/Government Relationships were Raymond L. Orbach, Chairman; Donald N. Langenberg; Cornelius J. Pings; and Monte C. Throdahl.

In addition to surveying the available literature, subcommittee members and staff met with selected officials from business, government, and the universities. At monthly meetings, invited speakers presented their views on pertinent aspects of the listed topics or on the broad purview of the Commission. The Commission received testimony on five university campuses from faculty members and administrators, as well as written comments stemming from invitations to research universities and from an open letter in *Science* magazine. Liaison with numerous government agencies was maintained through telephone contacts, correspondence, and attendance at Commission meetings. Approximately one hundred fifty persons gave advice and information to assist the Commission in its study. The Commission appreciated the efforts of all the participants in its deliberations and discussions. A description of these considerations and a partial list of individuals are contained in the Appendix.

The members of the Commission are listed inside the front cover. These individuals have backgrounds in education, business, and government. They accepted appointments to serve on the Commission without compensation. During Commission deliberations, they reflected their own experience and not necessarily the viewpoints of their institutions or organizations.

Liaison persons were designated to the Commission by the following government agencies: Alcohol, Drug Abuse, and Mental Health Administration (ADAMHA); Department of Defense (DOD); Department of Energy (DOE); Department of Health, Education, and Welfare (DHEW)*; General Accounting Office (GAO); National Aeronautics and Space Administration (NASA); National Institutes of Health (NIH); National Science Foundation (NSF); Office of Management and Budget (OMB); and Office of Science and Technology Policy (OSTP).

*After the Department of Health, Education, and Welfare became the Department of Health and Human Services and with the inception of the Department of Education, no new liaison persons were designated.

In its series of publications, the Commission reviewed the key elements of the present state of federally supported university research, affirmed what it believed to be good in this system, analyzed problem areas, and provided suggestions for actions to alleviate these problems. The Commission recognized that much diversity exists in the complex relationships among principal investigators, research administrators, and others in the university community, and program officers, auditors, administrators, and other government personnel. There is a wide range of beneficiaries, including industry, students, and the general public. The goals of the participating government organizations and educational institutions and of the concerned individuals involved in federally supported research are diverse and sometimes overlapping but not identical. Therefore, the Commission did not anticipate the ability to establish consensus on all of the issues. The Commission did seek to make a contribution to improved research in our nation by improving a system which produces a major portion of that research.

NATIONAL COMMISSION ON RESEARCH

Industry and the Universities: Developing Cooperative Research Relationships in the National Interest

Executive Summary

The theme of this report holds that improved university-industry cooperative research can produce significant benefits for the nation. It is in the government's interest to facilitate the relationship. Difficulties arise because of the very different character of the institutions and the responsibilities of the participants.

The Commission

The National Commission on Research was formed in late 1978 as an independent body. It was sponsored by interested organizations and supported principally by private foundations. The Commission was charged to study the relationship between the government and the research universities, to determine the nature and origins of the problems afflicting the relationship, and to recommend ways to solve these problems. Additional information on the origins and purposes of the Commission is contained in the Foreword (p. ix).

University-Industry Cooperative Research

Universities and technologically oriented companies function in different worlds. Yet there are many societal needs with dimensions exceeding the capabilities or scope of either universities or industry. The Commission recommends in this document that it is time to explore new ways for these two segments of society to produce synergistic results through programs of cooperative research.

The Introduction (p. 1) presents the opportunities which can develop from cooperative research relationships, while noting the very different roles of each of the participants. The section on background and history of the relationship between universities and industry (p. 3) begins with a discussion of the changing roles and objectives of the participants, placing research in the context of the innovation process. Trends in the support and performance of basic research between the 1950s and the present are displayed and summarized. These exhibit the increased role of government and the shift of expenditures by industry from basic research to applied research and development, although the level of funding for basic research by industry has risen in absolute terms. The consequences of lack of research cooperation between universities and industry are inefficient and unproductive dissemination of research results, and a lack of feedback from industry to universities concerning societal problems to the solution of which basic research could make relevant contributions. The relationship between universities, industry, and government is defined in the next section (p. 13) by first stating the fundamental principles which the Commission believes guides their actions; the benefits and hazards to each participant arising from the university-industry cooperative research relationship; and finally the roles and responsibilities of each participant requisite for the success of cooperative research programs. Selected alternatives for university-industry research relationships, including recent new initiatives, are described in the next section (p. 19). This section concludes with a discussion of government financial incentives for industrial support of university research.

Conclusions

The Commission reviewed the state of research and innovation in the United States. It also considered the variety of needs and philosophies that guide the actions of universities, industry, and the government. In light

TEAR SHEET—EXECUTIVE SUMMARY REPEATED ON PAGE xi.

of these factors, the Commission concludes that university-industry cooperative research relationships are beneficial and should be encouraged. More specifically, this report offers the following conclusions:

1. The ultimate result of any form of university-industry research relationship must be better products and services useful to the public.
2. Universities house the greater volume of basic research activity and are likely to continue to do so.
3. Research relationships between industry and universities can strengthen the innovation process and improve the vigor of research within the universities.
4. A close working relationship between the university researcher and the industrial counterpart is an imperative for a strong university-industry cooperative research program.
5. University-industry research relationships can contribute significantly to university research and instructional resources.
6. Equitable financial rewards should accrue to industry and to universities from explicit research relationships.
7. Hazards to university academic freedom from university-industry research relationships are manageable.
8. Universities, in seeking opportunities for cooperative research with industry, must exercise care to avoid subversion of proper university purposes.
9. Government can encourage and support the university-industry research relationship by becoming a facilitator rather than an ongoing participant in direction or management.
10. The less basic the research, the more difficult becomes the determination of whether the use of public funds for university-industry research relationships is proper.
11. The public must be informed of the nature and rationale of specific university-industry research relationships.
12. Misunderstanding and mistrust exist among members of industry, university students and faculty, and the general public, impeding cooperative research relationships between industry and universities. A new mechanism for discussion and resolution of the issues is needed.

Recommendations

An explanation of each recommendation is contained in the full report (p. 29). Recommendation 1 defines the character of the cooperative research relationship and is directed to all the participants. Recommendation 2 is directed at industry and suggests a mechanism for companies with common research interests. Recommendations 3 through 5 are directed to the Federal government and are mechanisms for facilitating the development of cooperative research relationships. Recommendation 6 deals with basic research relevant to regulatory policy. Recommendation 7 is directed to universities and outlines structural features which must be developed for administration of cooperative research relationships. Recommendations 8 and 9 are directed to both universities and industry and focus on public understanding of the cooperative research relationship.

1. The Commission recommends that research universities and industry explore effective cooperative research relationships which:

   a. Are designed around important scientific areas of mutual interest, individually tailored to the characteristics of each participant—emphasizing investigator-to-investigator interaction;

   b. Possess clearly stated objectives that preserve each partner's purposes and policies, recognizing that the often subtle differences fundamental to each partner must be understood and respected;

   c. Allow the individual researchers from both universities and industry to determine the specific choice of subjects to be investigated. Permit each partner's participants to share in any phase of the projects appropriate to their skills;

   d. Provide for financial reward to industry and to the university for assuming the risks of bringing highly uncertain scientific and technological programs to fruition and usefulness;

   e. Provide opportunities for demonstrating research performance and ethical qualities that will develop mutual respect for doing good science; and

   f. Develop a commitment for long-range support of research recognizing that meaningful research results are rarely achieved in short periods of time.

2. The Commission recommends that companies within a sector of industry review their research needs and explore the possibility of combining their resources for the support of a coordinated program of cooperative research with universities.

3. The Commission recommends that the Federal government encourage the application of research results to product development by permitting universities to retain title to inventions developed under federally supported research.

4. The Commission recommends that the Federal government provide financial incentives to initiate and maintain closer research ties between industry and universities. Tax policy provides an effective vehicle for such incentives.

5. The Commission recommends continued direct university-industry cooperative research relationships based on models which have proven effective. One such example is the National Science Foundation Industrial-University Cooperative Research Project Program.

6. The Commission recommends that university researchers be encouraged to contribute to the research knowledge base required for regulatory policy, particularly in the biological/environmental area.

7. The Commission recommends that universities examine their administrative structures and policies relevant to cooperative research arrangements with industry. Such research arrangements should facilitate cooperation, while protecting the academic research environment. Universities also should examine their patent policies and be sure they have staff capable of identifying and pursuing patent opportunities.

8. The Commission recommends that universities and industry take steps toward removing the misunderstanding and mistrust between them.

9. The Commission recommends that universities and industry inform the public of the rationale for their participation in cooperative research programs. They must make public the developing relationships and the outcome of cooperative research programs.

Introduction

> The Panel senses that there has been an ever widening gap between the university and industrial communities and as a result this key national source of new technological knowledge is not being adequately tapped for its innovative potential by the private sector—the sector with a major responsibility for innovation in the United States.
>
> **Advisory Committee on**
> **Industrial Innovation**
> **Domestic Policy Review, 1979**
> **U.S. Department of Commerce**[1]

University and industry relationships in America have had a long and unique history of constructive interaction. Several connections are long established and continuing. Officers of universities typically are members of the governing boards of major corporations, and virtually all universities have industrial executives among their trustees. Faculty members consult with industry and industrial experts often serve as adjunct faculty. Industry, particularly in high technology sectors, employs persons with advanced university training. Such relationships have remained a common feature of campus and industrial life.

New Possibilities

In the last decade, some leaders in universities and industry sensed a new possibility for this collaboration. They perceived a number of forces present in our society suggesting the right conditions for innovative cooperation of a kind and scale not before experienced, and, as discussed later, they have recently taken a number of important initiatives. Two examples of these conditions follow.

One example is that the combined research resources—intellectual and financial—of universities and industry could produce results greater than the research productivity of both acting separately. This will be true only if such resources are placed together in exceptional ways.

A second example is the increased public awareness and interest in complex issues rooted in fundamental scientific principles. Public policy debates on issues such as ecology, human health, and energy depend heavily on technical questions beyond current knowledge but within the reach of basic research not yet undertaken. High quality scientific inquiry is needed, and some of this research is very basic in character. Both industry and universities have certain capacities to conduct this basic research. However, the universities enjoy greater public credibility to assist both the government and industry in developing greater understanding of the scientific elements which may contribute to a better human environment.

The theme of this report is that this relationship currently has an opportunity for growth, and out of that growth will come increased innovation. This report suggests new ways that the research interactions between research universities and high technology companies can be tested under conditions that should produce measurable results.

Prospects

Several factors influence the prospects for benefits resulting from expanded university-industry research relationships. Three deserve special mention: a current concern over lagging innovation; a lack of rapport because prior interaction was modest; and the respective roles of the potential partners and of the government.

Lagging Innovation

There is widespread and serious concern among leaders in government, the universities, and industry over the erosion of U.S. hegemony in science, technology, and rates of productivity. Much of this concern focuses on lagging innovation, on the idea that the U.S. has not maintained the innovative characteristics which fueled its earlier scientific and economic success. The government could contribute to the improvement of these conditions by reducing the confusing array of legal and regulatory barriers. Enhanced joint university-industry cooperative research programs could make a significant contribution toward improving the climate for innovation in the United States.

Lack of Rapport

Direct industry support of basic research at universities could enhance innovation, but such support has been weak and spotty. There are presently several forms of support, varying from unrestricted grants to contracts for specified work. Some grants have been generous, but most have not been of critical size or of long duration. There has been little rapport built among universities and corporations from these types of funding relationships.

Respective Roles

There are some overlapping elements in the respective roles of universities, industry, and government. In their own manner, each acts in ways to serve the public interest. Universities, in carrying out instruction, research, and public service, serve many sectors of society. University researchers review potential intellectual opportunities and select areas for the pursuit of new knowledge as freely as practicable. Industrial organizations determine future products based on their assessment of public wants and needs in a competitive environment. This is done in the context of generating an appropriate return on the invested capital of the owners. Thus, corporate managers choose research by criteria which are very different from those of universities. Consumer demand, competition, and profitability are not usually considered by academic scientists, but each is a major influence in the industrial choice of research areas. The government seeks to advance the public interest in several ways related to research, including support, regulation, and an attempt to make available the knowledge generated through the research the government supports. The universities, industry, and the government may each influence the amount of innovation by the way they perceive and carry out their respective roles.

Structure of the Report

Following this introductory section, this report continues with a section on the background of the current university-industry relationship. It begins with a short history of the role universities, industry, and government played in the support and performance of basic research in the United States between the early 1950s and the present time. The third section presents statements of the principles, benefits, and hazards, as well as roles and responsibilities for each of the partners in this relationship. Selected alternative relationships are described in the next section. Conclusions and Recommendations are contained in the last two sections.

Our study of the issues has been made with available data. We have not generated new data. The Commission consulted widely with participants throughout the research community. This document attempts to present the current situation, define an improved relationship, review alternative means of cooperation, draw conclusions, and present recommendations. Where appropriate, specific examples are cited, but we do not give an exhaustive survey of all activities.

Some Caveats

Enhancing the research relationship between universities and industry is a complicated and perhaps risky enterprise. Nevertheless, we believe the potential benefits to the nation are sufficiently large to warrant a significant expansion of this nascent relationship. However, no simple single action will bring this about or resolve some of the issues identified in this report. Instead, a combination of steps, involving collaborative research projects chosen from a large number of alternatives, with concomitant structural adjustment, will be necessary to build a research relationship that will be of substantial benefit to the nation. We note in advance that such relationships may not be attractive to every university or to every corporation. Their diversity will mean different models for many, and no relationship for some.

Background and History

Changing Roles and Objectives of Participants

This report is about research, innovation, and the public good. It is a discussion of ways to encourage interdependent, supportive relationships among universities, the high technology industrial sector, and the Federal government, and ways to bring these relationships to fruition for the benefit of the public.

In the United States, the high regard for science and technology following World War II has given way in recent years to concerns about science and a faltering of the idea that scientific progress automatically signifies public progress. This change in attitude has coincided with a declining trend in the amount of real funds available to researchers, despite an upsurge in the resources required to pursue basic research.

Originating seminal ideas and selecting projects for university basic research are essentially uncertain processes. They build upon inductive leaps and careful attention to continual regrouping and reordering of bodies of knowledge—processes that reveal gaps of information.

There is a belief among scientists and some of the public that basic research should be supported, as Mallory said about the climbing of Mt. Everest, "because it is there." In fact, the public supports basic research because it expects benefits will follow.

In an earlier time, persons who thought about ideas, or who sought answers to questions through experiment and proof, were supported by private resources of their own, or they found a patron.

In the United States, prior to World War II, Federal government involvement in—and financial support for—scientific investigation was both modest and sporadic. National laboratories, organized and funded by government in the European tradition, have never become a dominant force in basic research in the United States. Rather, the university became the early bastion of research in this country. Teaching the tools required for research involved doing research. Eventually, the doing of research became a university pursuit in its own right.

After World War II, things changed. A growing number of Federal government agencies were asking questions of general importance about national defense, health, energy, agriculture, and transportation. Research attracted public interest and there was a new demand for university research from the Federal government

For the past 25 years or so, federal agencies have provided the major part of resources for university research. But in those same 25 years, science itself has changed. Knowledge has expanded tremendously, with a concomitant increase in scientific manpower. There has been an explosion of scientific instrument development. Costs of advanced research have soared. Exceptional services and facilities—such as worldwide computerized library interconnections—have become available. Almost all the sciences have ceased to be independent; interdisciplinary pursuits are much more common.

The interests of federal agencies have changed. Today, there is more emphasis on short-term results, though long-term research is still supported. Goals are more conservative. Once we aimed at the moon and even beyond—now we often limit our sights to what is expected. This growing conservatism from the traditional supporters of research is compounded by the very bigness of current science and the expense and sophistication needed merely to handle research tools. These requirements can preclude the randomness with which scientific questioning often was identified in the past. Serious researchers today may not be able to afford to ask many random questions. While the scope of research has expanded, the sources for funding have diminished.

While these changes were taking place in universities and government, the response in industry was mixed. Some of the mature industries were living on past achievements, and new products were being based on science and technology developed during the two decades after World War II.

But other sectors of the industrial community were experiencing some startling successes. The results included new fibers that made "wash and wear" a household phrase. Television sets got bigger; calculators got smaller. Farms became more productive; infectious diseases became less common.

There was yet another change taking place: a societal change. Pollution became as much a concern as progress. Relations between universities and industry—never really intimate—became strained. The Vietnam War aggravated this condition. Social criticism and campus protests alienated the private sector.

The seeming insensitivity of industry to the common good alienated a newly aware generation of students—and many of their professors. It usually did not come to open hostility between the two communities, but it certainly resulted in a standoff.

Meanwhile, changing national priorities and the outbreak of chronic inflation meant a relative erosion of federal funds for research. The space program was curtailed, but this was merely the most visible of the changes in federal support for research.

The present research climate has many problems. Innovation is lagging in the U.S., and some believe the replenishment of the bank of basic knowledge also has slowed. While the needs of "big science" have increased, inflation has strapped the sources of funding—both public and private. Regulations and tight money have further diverted resources away from innovation. Society's demands are increasing for academic institutions to provide both the educated personnel and creative ideas to meet national needs.

At the same time, there appears to be a new willingness for universities to seek and accept research support from the private sector.

This new attitude requires a perspective on three inter-connected elements: research, innovation, and meeting public needs. For clarity, these terms are used in this report to mean the following. By *research* is meant exploration, discovery, explanation. It is searching for the new, and once it is found, verifying the finding. "Technology" is applying that new knowledge—putting it to some practical use. *Innovation* is the process of discovery and the fount of new ideas springing from discovery into practical processes, products, or services to meet the needs of society. It generally requires working at the forefront of knowledge, being one step ahead of the competitor. It involves risk, but the returns on success can, and should, be high. *Public needs* are more difficult to define explicitly. They are a composite of individual value judgments, constantly shifting and changing but ultimately reflected in the marketplace.

There has always been an implicit link between basic university research and industrial innovation. Figure 1 on page 5 illustrates this process. The process of innovation and invention focuses basic research to yield useful, identifiable products. Between the area of basic research and the development area is an overlap area where feasibility of technological development is determined.

The portion to the left of the feasibility area is a region in which universities are preeminent and contains the greatest randomness. This area is the most unmanageable, in the sense that it requires faith in the creative genius of investigators. In this area are the seminal questions and the innovative answers.

The portion immediately to the right of the feasibility area, applied research, is more the province of industry than university, though the latter may make important contributions. Proceeding further to the right, one passes to the unique province of industry. Industry is most able to bring order out of randomness—to develop and commercialize research through innovation.

Public consciousness covers the entire process, although it is usually low at the basic research point of the diagram, and high at the commercialization portion.

One important concern is that no participant in this process unfairly exploit any other. If universities make initial discoveries in the area of basic research, these institutions should benefit from ultimate commercialization. At the same time, the requirements of the corporation to improve the rewards for shareowner investment must be met.

Accommodating all these needs into the random process of basic research, into decisions about feasibility, into innovative development, and into commercialization, can be a difficult and demanding process.

Figure 2 on page 6 illustrates the extent to which industry has concentrated its efforts in the applied and development areas and correspondingly how the universities have focused more on basic research. Figure 2 also emphasizes the substantial financial commitment that is required to program new discoveries through applied research and development as contrasted with the expenditures dedicated to the discovery of new ideas. While this division of labors will no doubt continue, it is hoped that financial and personal interactions between industry and universities can be strengthened along the entire continuum of the innovation process.

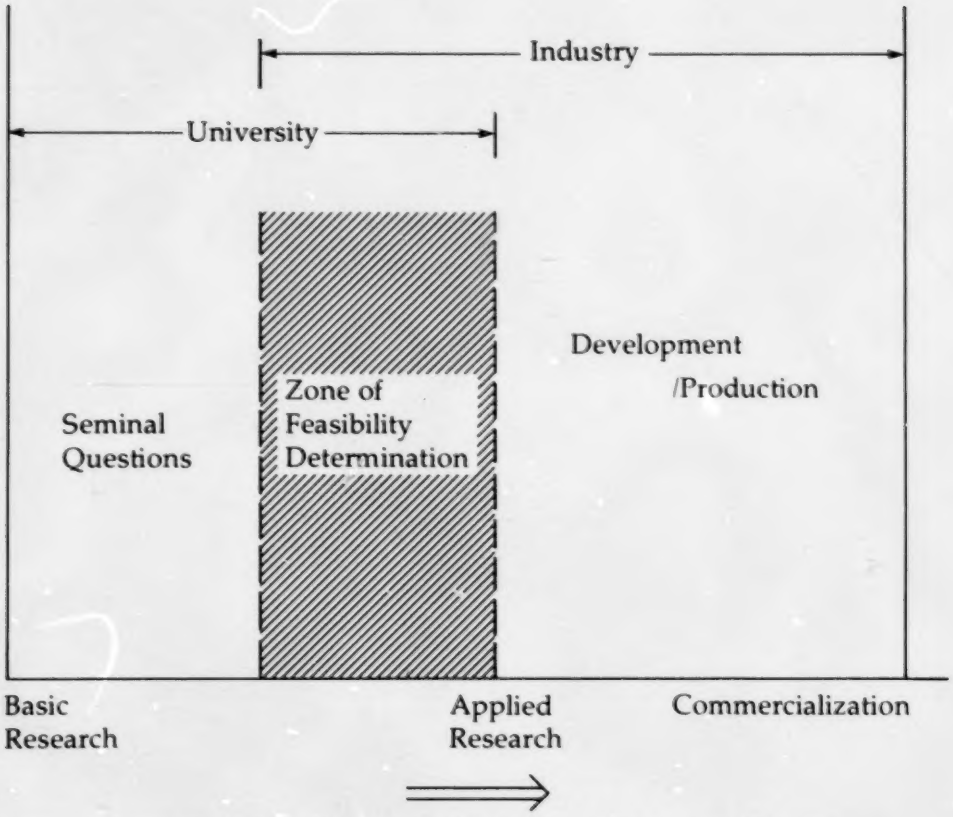
Trends in Basic Research Performance and Support, 1953-1978

This section explores the changes in funding patterns for research in the United States between 1953 and the present. This period is chosen because it begins with pre-Sputnik times, includes the late 1950s and 1960s when rapid expansion of the scientific enterprise took place, and the 1970s when expenditures were nearly level in constant dollars. The data we employ is taken from the NSF study, *National Patterns of R & D Resources, 1953-1978-79.*[2] A warning on the data is needed. Reporting procedures have changed over this period, the data are fraught with omissions, and different studies will exhibit different figures. Our focus is on the changes in the patterns of funding and expenditure over these 25 years, not on the absolute value of the data. The changes in the data exhibit internal consistency. In any case, the Commission believes that there is no better information available.

The research and development spectrum is very broad, with ill-defined boundaries between basic and applied research, and development. Reporting all three classes individually, or a combination of all three, diverts attention

Figure 1

Organization Involvement in the Innovation Process



from the university's greatest strength—basic research. The Commission believes that basic research is the most important ingredient of the national innovation process. The basic researcher asks the seminal questions which are eventually responsible for the greatest advances in productivity. It is germane to examine the changing expenditure patterns of the two principal basic research performers, industry and universities, and the sources of funding for both. This choice will considerably understate industrial support of total university research, because it omits industrial contributions to university applied research.

Subsequent sections of this report include university applied research in our considerations. Many of our recommendations are based on the total university research program, inclusive of both basic and applied research. Sensible separation of basic and applied research is not possible even if it were desirable. Both are important to national productivity goals.

The data below compare the character of the support for the national basic research effort in 1953 with more recent times. According to the NSF study[2], basic research *expenditures* of industry and universities have changed in the following manner since 1953, through 1978.

First, consider expenditures for basic research by performer for the years 1953, 1960, 1970, and (estimated) 1978.

TABLE 1
Total Expenditures for Basic Research
(current dollars in millions)

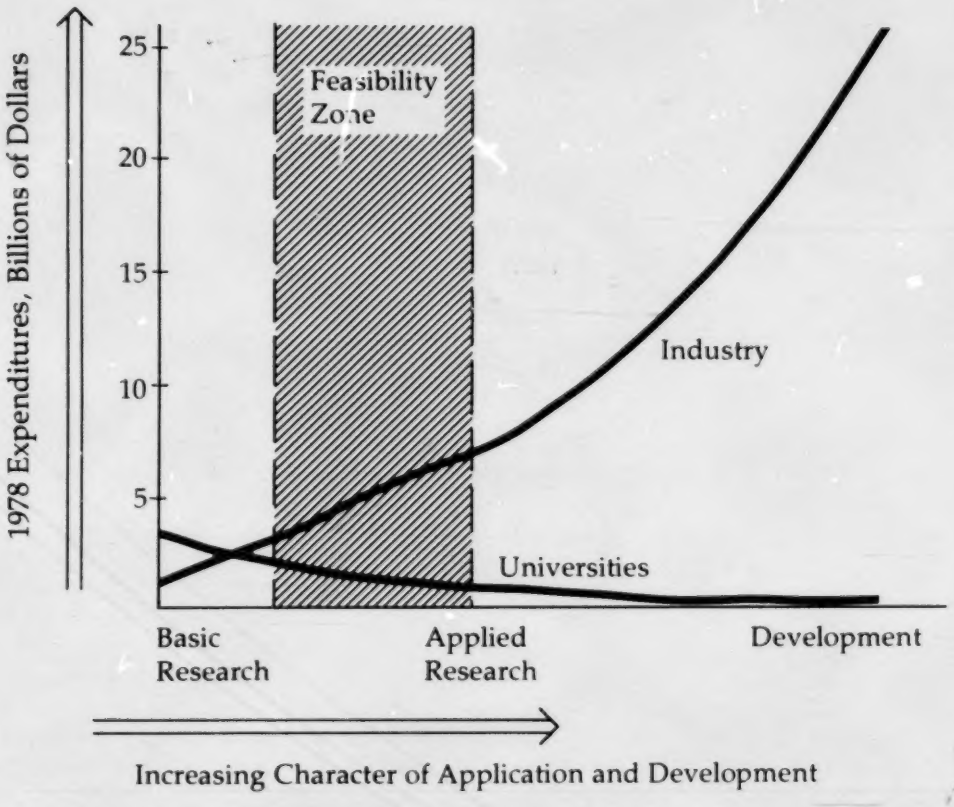
Performer	1953	1960	1970	1978 (est.)
Industry	151	376	602	975
Universities	110	433	1,796	3,165

Figure 2

University and Industry Research and Development Spending Patterns

1978 Billions of Dollars

	Basic Research	Applied Research	Development
University	3.0	1.2	0.2
Industry	1.0	6.0	26.0



[Data source: National Science Foundation]

21

Next, consider the sources of these expenditures. The charts on pages 8 and 9 show the percentages for the various sources of funding for basic research for each performer. The total area of each chart is related to the total expenditure for the basic research by the respective performer. It is important to note that these are shown in *constant* 1972 dollars in order to eliminate the distorting effects of inflation. Rounding errors are responsible for the total percentage differing slightly from 100%.

Four pairs of charts are presented, depicting the overall expenditures for basic research by two performers, industry and universities, and the distribution of sources in four selected years, 1953, 1960, 1970, and 1978. The "industry" source of funding of basic research performed by industry includes all sources other than the Federal government. The "universities and colleges" and "other nonprofit institutions" sources of funding of basic research performed by universities include state and local government sources, and industrial sponsored philanthropic institutions, respectively.

In the seven years from 1953 to 1960, the Federal government increased significantly its amount of funding for basic research within industry and roughly doubled the federal fraction of support. At the same time, industrial support of basic research in universities dropped by half in percentage figures though doubling in absolute figures. A similar change of scale occurred in the decade of the 1960s.

By 1960, the performers had reversed their relative 1953 positions of support, with universities outspending industry on basic research. This trend greatly accelerated during the 1960s, so that by 1970, universities spent approximately three times the amount of industrial support on basic research. The most recent available figures of 1978 differ little from those of 1970 in either constant dollar magnitude or relative share.

Summing up, the ratios of increased expenditures for the support of basic research from 1953 to 1978, measured in constant 1972 dollars, are:

TABLE 2
Ratios of Increased Expenditures

Sources of Funds	Performers of Basic Research	
	Industry	University
Federal government	4.6	12
Industry	2.2	2.7
University and Colleges	—	23
Other Nonprofit	—	5.6

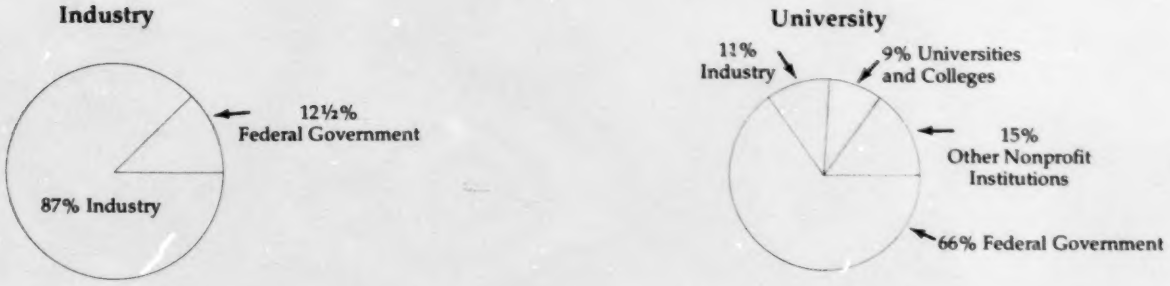
These data show that government support for basic research in industry has grown twice as fast as industrial support. Further, government support for basic research in universities has grown four times as fast as industrial support for research performed within universities. The apparent explosion of support from universities and colleges is mainly from state and local government sources. These increases probably result in part from changes in reporting procedures, although this cause cannot be isolated. By 1978, direct industrial support for university basic research had become almost miniscule as a percentage factor. Figures 3 and 4 on page 10 exhibit these changes in current dollars and constant 1972 dollars for easier interpretation.

These charts, tables, and figures, in conjunction with Figure 2, display the point that the industrial share of the funding of university basic research dropped by 75% between 1953 and 1978. As a percentage of the basic research effort by all performers, industry's support in 1953 represented 50%, whereas in 1960 the figure was 20%, and in 1978, 18%.

These changes took place during a period in which companies spent a constant 2% of their net sales on research and development. Within this constant proportion, there was a shift in expenditures toward applied research and development, as illustrated in Figure 2. However, industry has increased expenditures for research and development generally. Further, industrial support for *all* research at universities, represents a fraction twice as large as that for only basic research. Thus, the charts do understate the magnitude of total industrial support for university research.

Expenditures by Performer

1953



Total 1953 Expenditures for Basic Research

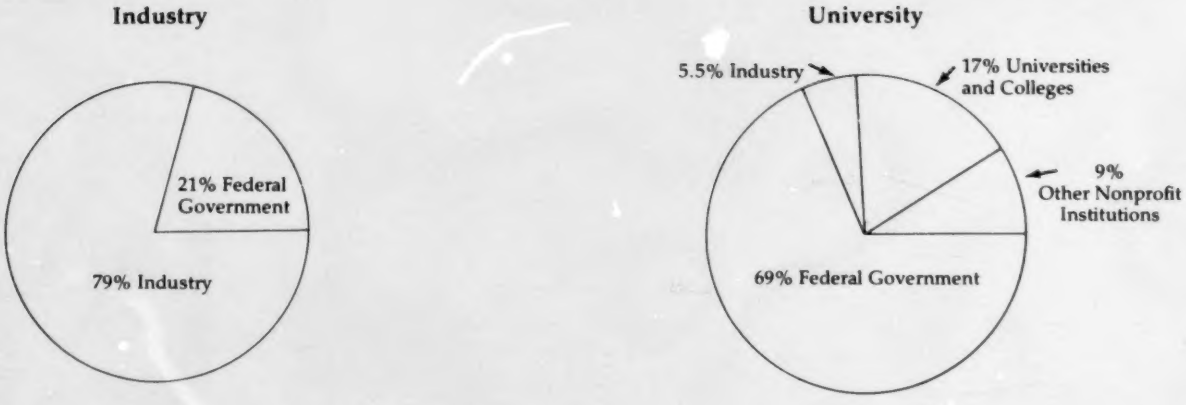
Industry:

$151 M current dollars
$256 M constant 1972 dollars

University:

$110 M current dollars
$187 M constant 1972 dollars

1960



Total 1960 Expenditures for Basic Research

Industry:

$376 M current dollars
$547 constant 1972 dollars

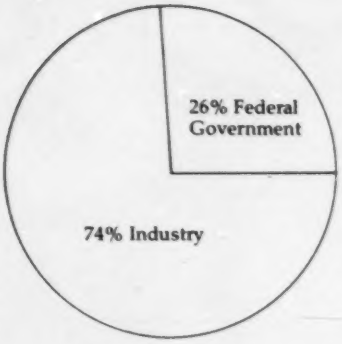
University:

$433 M current dollars
$630 M constant 1972 dollars

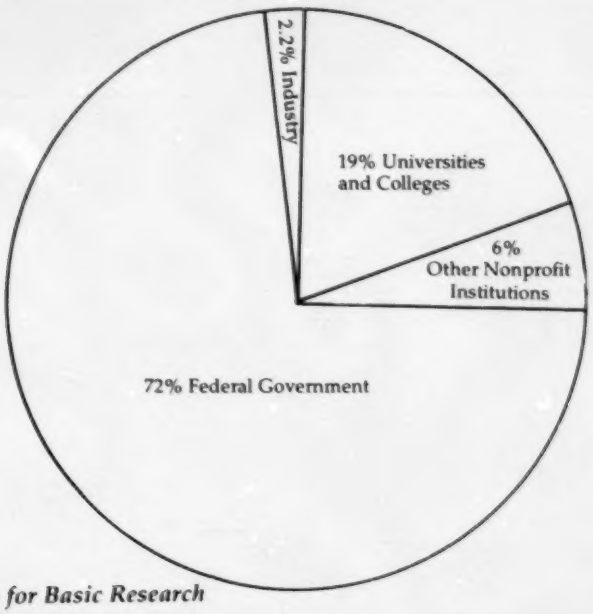
Expenditures By Performer

1970

Industry



University



Total 1970 Expenditures for Basic Research

Industry:

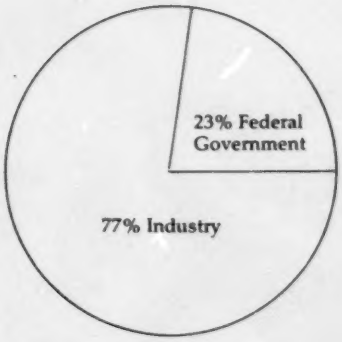
$602 M current dollars
$659 M constant 1972 dollars

University:

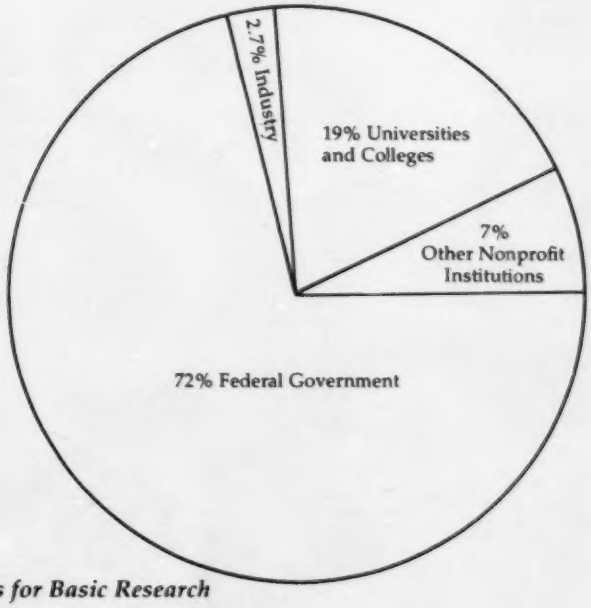
$1796 M current dollars
$1967 M constant 1972 dollars

1978

Industry



University



Total 1978 Expenditures for Basic Research

Industry:

$975 M current dollars
$642 M constant 1972 dollars

University:

$3165 M current dollars
$2084 M constant 1972 dollars

Figure 3

Funds Expended Annually for Performance of Basic Research by Universities and Colleges

(Billions of current dollars)

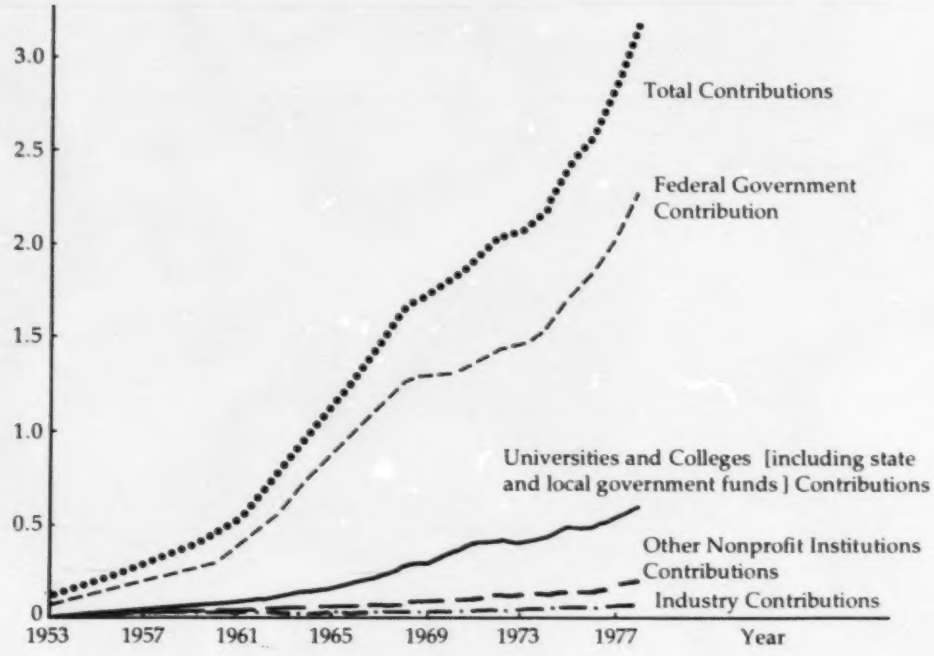
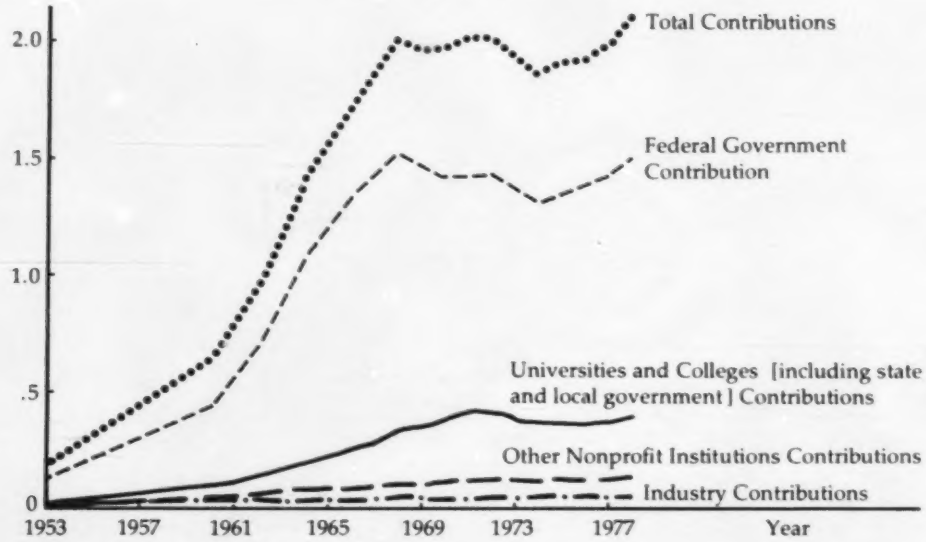


Figure 4

Funds Expended Annually for Performance of Basic Research By Universities and Colleges

(Billions of constant 1972 dollars)



The Commission believes it is in the national interest for industry to increase its participation in the national *basic* research enterprise. At the least, this means a reappraisal by industry of the balance of its expenditures across the research and development process continuum, as shown in Figure 2. For their part, the universities should ensure that the quality of university-based basic research is sufficient to warrant any increase in support which might result from such an industry reappraisal.

There are many reasons for industry's declining share of basic research funding. Basic research has a very small present value when viewed in strictly economic terms. Expenditures for basic research must be discounted for ten or more years. Current high interest rates, along with uncertainty about the future economic climate, make such investment considerably less attractive than in previous years. Basic research is, therefore, a marginal investment for industry. Expanding regulations and uncertainties about future regulations also have caused industry to pull back at the margin and move toward shorter term and less risky research. In addition, the effects of government regulation are more severe on smaller and newer firms which can less afford to expand to accommodate needed research programs.[3]

Consequences

Two consequences of the apparent lack of cooperation between industry and university research are inefficient and unproductive dissemination of research results to industry, and a possible lack of the feedback needed to facilitate university basic research on societal problems to which industry could contribute.

Dissemination of Research Results

The lack of an active cooperative research relationship between universities and industry makes the dissemination of university-generated research results and their incorporation into product development random and uncertain. Publication of research results in a literature, which is ever increasing in scope and volume, does not communicate well for industry. For industry, it appears as "noise," in the technical sense of the word. It becomes difficult or impossible for industry to identify and relate research results of potential importance for future economic success.

A linkage is necessary between universities and industry which will allow the latter to monitor and transfer relevant research more directly into the innovation process. To a considerable extent, this communication does exist in agriculture. The Morrill Act and the land-grant college system it spawned have resulted in agricultural experiment stations dispersed amongst the farming communities, with close ties to agricultural research departments in colleges and universities. Linkages on this scale are largely absent from the physical and biological sciences. Their establishment requires that the university researcher, and his or her industrial counterpart with similar interests, skills, and knowledge, begin to talk together. The most effective vehicle for this communication is a cooperative research program.

Lack of Feedback from Industry to Universities Concerning Societal Problems

Both universities and industry must serve the public needs. Universities lack feedback from industry concerning societal problems for which basic research could make relevant contributions. However, the choice of direction by each institution will depend on a complex of factors. For industry, this ultimately involves financial return on investment. For the university, the definition of seminal questions, and choosing which problem to attack, depends on the initiative of the individual researcher and his or her sense of research opportunity. The diminished involvement of industry in university research means that problems encountered in the innovation process by industry may not be known to university researchers. Opportunities for research can emerge from a knowledge of industrial programs of research and development, and they can be missed simply because of lack of communication. Communication between university and industry researchers benefits both, enriching the university intellectual environment, as well as contributing to the innovation process. Problems that industry faces can present exciting research challenges to the university researcher. In this manner, the traditional freedom of choice so important to high quality research in universities can be entirely consistent with university researchers contributing to the innovation process.

In summary, the past quarter century has witnessed a large increase in Federal, state, and local government funding of basic research in universities. The proportion of industrial contribution to basic research in universities has fallen markedly. Currently it is so low a percentage that, even if it were influential in setting research direction

in the past, it could hardly be regarded so today. This has contributed to an isolation of industry from the university researcher in many disciplines, and made information transfer between universities and industry even more difficult.

The Commission believes this separation between university and industry research is a serious problem. The next section describes the basic premises used to ground the discussion of future possibilities and the conclusions and recommendations of this report.

Defining the Relationship

There is an apparent contradiction which bedevils the universities and industry in their research relationships. Their institutional objectives are quite different, yet they have sometimes cooperated when mutual interests were served. When the possibilities of mutual institutional benefit are recognized, however, the university-industry cooperative research relationship must be founded on relationships between individuals. The university researcher and his or her industrial counterpart must go beyond exchanging research results. They must communicate at all levels, discussing failures as well as successes. Only in this manner can the information transfer work to enrich the university research and instructional environment while also contributing to the industrial innovation process.

The role of government in such a relationship should be that of facilitator. Its proper function is to help create conditions in which university-industry relationships can flourish, without defining, directing, or unnecessarily regulating the relationships. Financial assistance from the government to encourage the research connection between universities and industry can be a very important factor. It can take the form of direct support, as in the National Science Foundation's University-Industry Cooperative Research Centers, or the newly formed Cooperative Automotive Research Program, or of indirect support, as in the proposed Research Revitalization Act of 1980, HR 6632. This bill, introduced by Congressman Charles A. Vanik with over sixty Congressional co-sponsors, contains provision for a 25% tax credit when industry directly supports research in universities.

In order to establish a framework for our subsequent conclusions and recommendations concerning a cooperative research relationship, this report points out potential benefits and hazards to the universities, to industry, and to the government. It also lists their roles and responsibilities.

Fundamental Principles of the Participants

There are philosophical principles which define the purpose and guide the actions of all three partners involved in the support of research in the United States. Recognition and appreciation of these principles are prerequisites for good working relationships.

The stated principles may appear obvious to persons in each of these three sectors. Nevertheless, the Commission has observed that there is a mutual lack of understanding of these principles and their importance.

Within the framework of the principles, the benefits and hazards of the research relationship between the partners, as well as their individual roles and responsibilities, can be defined. Having reviewed these factors, the complexity of the three-way relationship, and the difficulties associated with cooperative research, should become more apparent.

Fundamental Principles for the Research Universities

1. *The pursuit of new knowledge is one of the principal functions of a research university.*

The research university in the United States has become and should remain the principal center of fundamental research and scholarship. As a research center, it is an institution of unsurpassed performance, a model eagerly emulated by other nations.

2. *Freedom is essential to inquiry.*

The freedom of the scholar to pursue new knowledge wherever the paths of discovery may lead is essential to high achievement in research. This freedom is not absolute. It is limited in principle by moral and ethical constraints and in practice by the availability of resources. Interference in the selection process for new directions in research on the basis of immediate relevance delays discovery, wastes talented minds, and weakens the spirit of inquiry.

3. *Research and teaching are inseparable.*

The search for new knowledge and the preservation and dissemination of established learning are interwoven in a research university; each makes an invaluable contribution to the other. Universities must not engage in activities which do not contribute to the instructional process.

4. *Diversity among research universities is a source of strength for the research program of the nation.*

Singly, each university provides strength in certain fields; together, the universities provide strength in all fields. The universities are diverse not only in the areas of strength, but also in their organization for research.

The organizational differences derive partly from the decentralized way in which American higher education evolved and partly from research itself. Since research by its nature encounters the novel, the unknown, and the unexpected, universities naturally developed different approaches, practices, and structures for research. Such differences develop even within a single institution and are themselves a source of strength. Research relationships with industry should not be expected to be uniform or general.

Fundamental Principles for Industry

1. *Profitability is a major objective of industry.*

Private industry is responsible for making a financial return on invested capital of owners. Without profitability, it will cease to exist. Industry must balance short-term profitability with long-term survival. It must invest its resources wisely to ensure its future participation in the marketplace.

2. *Financial rewards are essential for assuming risks.*

The innovation process is a key to providing useful products and services.

Personal and organizational risks are inherent in dealing with the uncertainties of the innovation process and are stimuli to those so involved. Time needed to achieve successful results is much longer than usually estimated. Timing is critical when the state of development of the art matches readiness of the public to accept the innovation. Uncertainty is present in many forms.

Individuals and industrial organizations have a right to rewards or penalties for accepting these risks.

Successful industrial organizations must continually generate new knowledge internally or acquire it from the public domain in an ethical manner for expected future use. They may do this by plowing back a substantial portion of any profits into research and development.

3. *Efficient provision of useful products and services is one of the prime functions of industry.*

Anticipating, generating, and providing useful products and services which require timely application of new technology is the central purpose of industry. No other type of organization is equipped with resources and skills to serve society in that way. To the extent that progress continues to be accepted as a useful concept, that economic and technological growth are considered attributes of worth, and that reason and its product of scientific knowledge are required tools for progress, the purpose and obligation of the private sector become enmeshed in anticipating wants and needs of society. Industry must perform this function in a socially responsible manner, with public health and safety as prime considerations.

4. *Freedom to carry out or financially support all types of research and development is crucial to industry.*

Industrial organizations continually generate or acquire new scientific and technical knowledge for future use by plowing back substantial portions of their after-tax profits into both basic and applied research and development.

Research in many disciplines and forms is the starting point for implementing the innovation process.

Industrial organizations should be free to carry out research, either internally or jointly with others, and do so anywhere in the world in their own enlightened self interests. Conversely, it is appropriate for universities to work cooperatively with industrial organizations on research matters, provided they obtain full remuneration for their efforts.

Fundamental Principles for the Federal Government

1. *Government support of research is in the national interest.*

The government supports the research and scholarship leading to new knowledge because of its responsibilities for the security and welfare of the nation. This principle has been stated explicitly in presidential, congressional, and budgetary pronouncements. In supporting research, the government is not bestowing gifts or favors on institutions or individuals. Rather, it is building and renewing public investment in an important public asset. Government support may mean direct financial support or the encouragement and facilitation of financial support by other institutions such as industry and universities.

2. *Maintaining a healthy economy is an important government responsibility.*

The government is responsible for ensuring that the public interest is served by all the major elements which influence the economic well-being of the country. When the private sector is unable or unwilling to develop the innovation process, it is a government responsibility to remove artificial barriers and other constraints, and provide incentives consistent with the public good.

Benefits and Hazards of the Relationship

The following array of benefits and hazards presents a complexity which could discourage research cooperation. The purpose of this presentation is to guide prospective participants in appreciating fully the possible rewards and in avoiding the pitfalls. For the ease of the reader, this material is summarized in tabular form on page 16, together with the roles and responsibilities of each partner.

Benefits to the University and University Researcher

1. *A "market connection."* This will acquaint the university researcher with the process of innovation, development, and marketing opportunities for industry. This can lead to a better understanding of the innovation process and can generate or stimulate new opportunities for research.

2. *Access to additional or complementary technical and physical resources made available by industry.* An example of physical resources is equipment, while examples of technical resources include synthesis and analysis capabilities.

3. *Curriculum enrichment as a consequence of communication with industry.* Understanding the innovation process helps the student and the faculty to see the role of technology in our nation's economy and how the investigator's research effort can contribute.

4. *Patent licenses.* These could grow out of a research relationship with industry, and could add modestly to the resources of the university for funding research. Such licenses could provide the university with options for support of new research directions and maintaining research capacity. This topic is discussed more fully in a previous report of the National Commission on Research, *Funding Mechanisms: Balancing Objectives and Resources in University Research.*[4]

5. *Longer term and consistent additional funding for research.* A number of recent examples are discussed below in the section on Selected Alternatives beginning on page 19.

6. *Research relationships with industry involving less paperwork and administration than federal funding agencies require.*

7. *Enhanced public credibility for service to society.* Contributing to the innovation process and adding to the research base important to regulatory policy are explicit demonstrations of university research contributions to public needs.

Benefits to Industry

1. *Improved accessibility to students and faculty.* Acquainting students with the industrial research environment could influence their careers and make research and development positions with industry more attractive.

2. *An opportunity to influence future university research directions.* Increased responsiveness to industrial research needs can sometimes result.

3. *A source of skills and techniques for new fields.* Specialized equipment with large capital costs not justifiable in an industrial budget could become available. Much of this has been funded from Federal government sources. The skill and technique now solely possessed in universities utilizing such equipment could be shared.

4. *Expansion under favorable investment conditions in some additional areas of research.* By cooperating with universities, industrial research initiatives could be begun in a less expensive and perhaps more efficient manner than by direct creation of an industry intramural research program. Industry could experiment with research programs which do not appear to be central to its immediate interests.

5. *Increased access to peer review of industrial research.* The quality of research carried out within industry can be assessed where proprietary limitations make industrial participation in open scientific forums difficult.

6. *Excitement and enthusiasm generated by close contact with new research ideas and researchers.*

7. *Enhancement of industrial credibility in the eyes of the public after long-term research cooperation and demonstrated successes.*

TABLE 3

	Benefits of the Cooperative Research Relationship	Hazards of the Cooperative Research Relationship	Roles and Responsibilities of the Partners
Universities	1. Acquaintance with the marketplace and innovation process 2. Access to additional technical and physical resources 3. Enrichment of the curriculum 4. Income from patent licenses 5. Additional funding sources for research 6. Less paperwork and administrative burdens compared to direct government funding 7. Enhanced public credibility for service to society	1. Inhibition of unfettered choice of research direction 2. Temptation for more applied and development programs 3. Suspicion of use of university resources for private benefit 4. Polarization of opinion of special interest groups against universities	1. Protect the academic environment 2. Development of cooperative research framework 3. Insure industrial contributions as part of relationship 4. Inform university community of need and character of proprietary protections 5. Provide legal and policy guidance to participating faculty and students
Industry	1. Acquaint research students with industrial research environment 2. Influence future research directions 3. Source of new skills and techniques for research 4. Experiment more efficiently with new directions in research 5. Increase access to peer review 6. Generation of excitement and enthusiasm 7. Enhancement of public credibility	1. Loss of some control over a proprietary position 2. Lack of relevance of university research to industrial problems 3. Suspicion of use of university resources for private benefit	1. Provision of goods and services to meet public needs 2. Develop mechanisms for transfer of research into the innovation process 3. Commitment to develop research ideas, sharing benefits with university 4. Provision of long-term research support 5. Provision of access to industry equipment and processes for participating university research personnel
Government (Public Interest)	1. Improved innovation leads to long-term stable growth of the economy 2. More efficient flow of research knowledge into industry 3. Improvement of the science base for regulation	1. Potential for monopolistic action or restraint of trade 2. Co-mingling of public funds for research with privately supported programs	1. Lessen barriers and provide incentives for university-industry cooperative research 2. Support studies of potential problems in the relationship, and develop models 3. Support cooperative research where public payoff is high 4. Develop long-term perspective for cooperative research programs 5. Provision of financial incentives for industry support of research in universities

Benefits to the Government and the Public Interest

1. *Enhancement of the viability of American industry in the world competitive environment through improvements in industrial innovation.* A strong role of industry in research can provide manufacturing options for ten to fifteen years in the future, leading to long-term stable economic growth.

2. *More efficient flow of scientific research knowledge into industry.* It is in the public interest to improve the process of using the results of basic research in innovation.

3. *Improvement of the science base for biological and environmental regulations.* This could improve the objectivity of the regulatory process.

Hazards to the University

1. *Adverse effects on research directions and publication rights.* The research relationship with industry might lead to undue industrial direction of university-based research, thus threatening the freedom conducive to productive research. This problem works to the ultimate disadvantage of both parties.

2. *Inducement for universities to become involved in more applied and development-oriented programs.* This possibility leads to some neglect of the university basic research and teaching programs. Faculty or administration interest or the need for industrial research support may generate a temptation for the university to skew its research portfolio in undesirable directions.

3. *Strong public suspicions, and some outright opposition, to intensive university-industry research relationships.* The suspicion of commingling of university and private funds for private benefit can have serious consequences. This is especially significant for public institutions, but also has relevance for private institutions.

4. *Polarization of university and single interest groups against one another as a consequence of participation in research concerned with scientific questions of social importance.*

Hazards to Industry

1. *Loss of some control over a proprietary project.* For true cooperative relationships to flourish, industry will have to share some of its own research and development achievements with university researchers.

2. *Support of research irrelevant to long-term industrial development or production needs.* Though university researchers possess many peripheral interests which may make this a hazard, it can also become a benefit when unexpected new directions emerge.

3. *Public outcry when some perceive the research relationship to be against the public interest.* Public institutions are most susceptible, but private institutions can also fall victim to charges of untoward collusion with "big business."

Hazards to Government and the Public Interest

1. *Potential for monopolistic action or restraint of trade.* This may be a consequence of proprietary protection of research results with a company or select group of companies. The more the relationship focuses on basic research, the less the hazard.

2. *Diversion of public monies to private purposes.* Commingling without adequate accounting safeguards of government funds with private funds for research programs is a central part of this problem.

Roles and Responsibilities of the Partners

In order that joint relationships may flourish, all the partners must be aware of the individual purposes they serve and different requirements they bring to the relationship. (As noted above, the roles and responsibilities are presented in tabular form on page 16 along with the benefits and hazards for each party.)

Roles and Responsibilities of the University

1. *Protect its academic environment.* Universities must ensure that research and instruction are of the highest quality. This requires that the choice of research direction and dissemination of research results remain the province of the individual researcher.

2. *Develop sound cooperative research frameworks.* With appropriate consultation with industry and sometimes with government, cooperative research frameworks should be constructed which make clear the conditions, benefits, and hazards of the university-industry research relationship. Particular care should be taken to make this information available to the faculty, the students, and the general public. All of the participants must understand and be willing to abide by these conditions.

3. *Negotiate a cooperative structure for information sharing.* This must result in industry sharing its research knowledge with the appropriate university researchers.

4. *Inform the university community of the proprietary rights of industry.* The need of industry for some proprietary protection on research developments conceived jointly under cooperative agreements with university researchers must be well understood within universities.

5. *Provide policy and legal guidance to faculty and students interested in cooperative research with industry.* This will require that the university administration, in consultation with faculty and students, develop a framework for this purpose. Legal staff must be accessible and have an understanding of both the character of university research and the industrial marketplace.

Roles and Responsibilities of Industry

1. *Provide goods and services to meet public needs.* Industry's success will be determined by how well it achieves this ideal. Industry should provide the university researcher with an understanding of how research fits into that function and how the researcher contributes to the innovation process.

2. *Develop a means to utilize research.* Industry can do this by developing its own intramural research capability in order for its personnel to work most effectively with university researchers, or providing other means to transfer the results of university research into the innovation process.

3. *Exercise due diligence regarding research applications.* Industry should seek to develop and apply the results of cooperative research to production and sales whenever appropriate. It should commit itself to a development capability, and share the benefits of product development and production with the contributing research university.

4. *Make university research agreements with financial commitments covering more than a single year.* At a minimum, these should match in length the three- to four-year research period of a graduate student.

5. *Provide university researchers, where appropriate, with access to equipment and technical personnel within the industrial laboratory.*

Roles and Responsibilities of Government

1. *Lessen barriers and provide incentives regarding university-industry cooperative research.* When a consortium of industries sponsors a university research program with proprietary rights to research results, antitrust issues need to be understood by the participants. Statutes and regulations can be changed to allow universities to retain title to inventions arising from government supported research. This would serve as an incentive for more extensive research cooperation between universities and industry.

2. *Stimulate joint university-industry research by encouraging conferences to examine the problems faced by cooperative programs.* Construction of model patent and royalty agreements would provide assistance. Guidelines for multiple industry-university cooperative programs would lessen the dangers of participants engaging in monopolistic practices.

3. *Support joint university-industry research which has extraordinary potential for high public benefit but which is inappropriate for solely private pursuit.* For example, some research areas could yield results which may never return rewards to industrial firms which are properly balanced by the risk of private investment. Other instances, such as public utilities, require active government involvement. Government can identify and support concentrated programs of cooperative research in such areas to deal with research topics with important public interest aspects.

4. *Adopt a long-term approach in preparing and evaluating its initiatives to stimulate research cooperation between industry and the universities.*

5. *Provide financial incentives to industry for support of research in universities.* These may take different forms and can be tailored for specific purposes.

Selected Alternatives for University-Industry Research Relationships

Characteristics of Alternatives

In considering future alternatives, the Commission has been impressed by one condition frequently cited as necessary for any effective university-industry research linkage—sympathetic communication. The words "intimate," "long-term," and "committed" describe the relationships which are required for a productive partnership.

Some hostility towards the business community exists presently on the university campus, with some individuals and groups having an aversion to perceived business behavior and morality. This view has a long history, but was most conspicuous during the period of the United States' military activity in Southeast Asia. It included negative and sometimes violent receptions for business recruiters who appeared on college campuses. There was a breakdown of trust, and this heritage remains. By comparison, university personnel are often cited for a lack of sensitivity to the pressure of the marketplace. From the industrial point of view, a great deal of university research can seem irrelevant, and the university researcher often appears arrogant and uncooperative.

There must be an understanding of issues and a change of attitude on both sides. Industry must be prepared to give up some proprietary security; university researchers must be prepared to risk delay of publication because of potential patent applications. There are some promising new initiatives that have been taken by industry: the Monsanto-Harvard and the Exxon-MIT agreements discussed below are two examples. If such agreements prove highly productive, they likely will be pursued by other firms.

Universities are beset with demands for "neutrality." Some students and public interest groups are reluctant to see research relationships develop between university personnel and their industrial counterparts because they fear that the public purpose of the university will be compromised. Universities and industry can be intimidated by a class action suit against a university with industrial relationships.

Future alternatives for cooperation must seek to minimize these impediments. Dr. M. E. Pruitt, of the Dow Chemical Company, lists as his first agenda item for industry, ". . . develop a better understanding of universities—a realistic knowledge of the dimension, thrust, and problems of the universities;" and as his first agenda item for universities, "Develop a better understanding of industry through a better knowledge of its objectives and problems."[5] A first step is to bring together leaders from selected industrial research laboratories and their university counterparts for purposes of discussing mutual needs, goals, and objectives. There are already some examples of this type of collaboration.[5] Companies with common research interests could form an organization to make contracts with selected research universities for the purpose of developing new research relationships. This approach could improve understanding between both parties. Specific methods may be very different from industry to industry, from university to university, and in different geographic areas. But the underlying aim must be the same—to lessen the mistrust and misunderstanding between those who should be partners in the national research enterprise.

Another *sine qua non* is the ability of industry to translate the results of university-based research into technological innovations. It is difficult enough in high technology industries with sophisticated in-house research programs to transfer research results into development and production stages. It is nearly impossible to effect such transfer between the university and an industry which lacks a sophisticated research capability. One can liken the problem to that of an impedance mismatch in an electrical circuit. Mismatch results in strong reflection, without effective transmission. To allow productive communication, industry must ensure that it has within its own structure a facilitating element. Some part of the corporation must be involved in high quality research or have experience in identifying relevant research results and incorporating them into the development and production stages. This can be organized individually by companies, or collectively within an industry, e.g., the Electric Power Research Institute. The Commission is convinced that without such a matching condition, a productive university-industry research partnership cannot develop.

A word should be said about the importance of the cooperative research entrepreneur, whether from the university, industry, or government sector. Such an individual can be identified in almost every case where a university-industry research relationship of some magnitude has been fostered. The complexity of the relationship, the need for monitoring and trouble-shooting, and the need for continuity, all suggest the need for an enthusiastic and dedicated proponent who will see the project through to its conclusion. This leadership is useful sometimes even after the project has no longer any formal relationship to the founding organization. For example,

the MIT Polymer Processing Center discussed in Alternative 4 below is now independent of the National Science Foundation. However, it continues to involve its previous NSF program director in its deliberations.

Alternatives

Six alternative approaches for cooperative university-industry research relationships are presented. They are either being tried presently or are in the planning stages. Many of these already have proven effective, though on a small scale. We do not include all existing or proposed relationships, but have selected those we think possess widest interest. Our recommendations (p. 29) will be based on many of these possible relationships.

1. *Philanthropy* is a significant factor in the context of university research. As shown above in the section on background and history (p. 3), support from nonprofit institutions and foundations for university basic research increased fourteen-fold between 1953 and 1978, amounting to $215 million in 1978, or 7% of total university expenditures for basic research. Though this amount is three times the amount of direct industrial support for university basic research, one must remember that a good deal of this money distributed by foundations was generated by past profits of industry. In addition, some of the larger corporations have generous matching programs for voluntary employee contribution which produce substantial amounts in unrestricted and departmental grants to universities. Some such programs match dollar for dollar, while others provide higher ratios of corporate support. Philanthropy plays an important role in allowing the university to perform its research and instructional function.

2. *University-industry joint research relationships* with no government participation or encouragement are becoming more common. Occasionally, a consortium of companies agrees to fund a program in research in which they each supply participants and have open access to the results. One such program is the Silicon Structures Project at the California Institute of Technology. The participating companies send their scientists to the university to work actively in the project. In this manner, they transfer the results of the research into the innovation efforts of the company. The advantage of these programs is their self-sustaining character. The disadvantage from the commercial point of view is their non-exclusivity. The results are freely available, and only a limited technological lead accrues to the participating company.

Another more recent mode of industrial support of university research can be found in the Monsanto-Harvard University agreement and in the Exxon-MIT agreement. Both of these arrangements involve the selection of a small number of senior university researchers. In these examples, two such individuals are designated. The supporting company has full confidence in them and agrees to support their work for an extended period of time. In the case of the Monsanto-Harvard agreement, the statement of principles reads:

> An innovative relationship between university and industry, with due regard to the public interest, could provide large-scale manufacturing and distribution of new and necessary products, and possibly establish an entirely new industry based on Life Sciences.

The researchers at Harvard provide the conceptual framework, identify suitable personnel, and provide training in modern biology. Monsanto provides product identification and development, expertise in modern technology, as well as production and marketing. Arrangements are made for royalties and patents which appear to satisfy both partners. Long-term funding, over twelve years, at substantial annual amounts, allows the Harvard researchers to work in new areas of research without pressure for short-term results. The project can be terminated by either partner, but only with long-term notice. Both parties can publish their own work, with advance notice to the other. However, each is obliged to deal confidentially in mutually agreed areas.

The Exxon-MIT agreement is in the area of combustion. In addition to the two principal investigators, it involves a large group of students, post-doctoral fellows, and other university faculty. The agreement is nominally for ten years, with the provision that each principal investigator devotes up to 50% of his research time to the research agreement. The precise percentage is based on the joint decision of the investigators and a steering committee which approves the research program. A significant feature of the agreement provides that an additional 20% of the total spent on designated projects will be made available by Exxon to the MIT principal investigators for use as they see fit on combustion research. Under this agreement, MIT will have the first opportunity to patent research results, but Exxon will have royalty-free rights to use any patents which result from the research. In the words of Dr. Peter J. Lucchesi, Vice President for Corporate Research, Exxon Research and Engineering Company:

> . . . we have come to grips with the issue of freedom to publish, etc. It turns out that these issues, though important, are workable. What is overriding to the professor is that he get the long-term support, relatively free of red tape. He is willing under those circumstances to talk about a partnership. And you find that the problems can be worked out, although they are there, and shouldn't be minimized.[6]

Therefore, there are trade-offs for the university researcher, as well as dangers for the supporting company. There is no assurance that the fruits of these agreements will justify their rather large cost to the company.

An interesting aspect of both these agreements is the area of research which these two corporations chose to support. In the case of Monsanto, it was an attempt to obtain a "window on the new biology." Health issues have been of long-term interest to Monsanto, and it was felt that product insight or development might emerge from cooperative investigations in this field. In the case of Exxon, combustion was of concern to the company and a capability for this research existed within the firm. However, it was decided to draw on the scientific expertise of MIT in this area to explore aspects of the science underlying combustion phenomena.

As both companies have highly sophisticated basic research enterprises of their own, these matches to universities satisfied the necessary conditions presented previously. These examples may also provide a valuable alternative to industrial firms that are unsure about the relevance of research in a particular field to future product development or have a limited research capability of their own.

3. *Voluntary industrial associations* could be formed which would provide funds to support a research reserve for funding university research. Voluntary industry groupings have been formed for rather defensive purposes, especially in industries whose products are perceived to affect the environment. These associations themselves sometimes have sponsored independent research facilities. The participation of a presumed neutral third party, such as the university researcher, would add to the credibility of industrial intentions. Currently, much of the *scientific* work underlying regulatory policy is carried out by government and industry in an adversarial climate. The inclusion of the university with its capacity for independent research could ease those industry-government confrontations on scientific questions and could play an important role in enhancing the ultimate credibility of regulatory decisions in the eyes of the public.

4. *Direct government financing of cooperative research programs* provides models for development of university-industry research relationships. This section describes three such efforts: a) National Science Foundation Cooperative Research Centers, b) National Science Foundation Industrial-University Cooperative Research Projects, and c) the Cooperative Automotive Research Program (CARP).

The Cooperative Research Centers experiment carried out by the National Science Foundation is a mechanism in which the Federal government through an agency program officer plays an important role in the initial stages of a cooperative research program. The government reduces its financial contribution as the program matures and industry bears more of the burden. This program, initiated in 1972, spawned three initial efforts: Furniture R & D Applications Institute, based at North Carolina State University; New England Energy Development Systems, based at the MITRE Corporation; and the MIT Polymer Processing Center located at the Massachusetts Institute of Technology. Each of these centers was funded in 1973 for a five-year period. Of the three, the first did not work well for a variety of reasons, not least the lack of commitment from the industrial partners involved. In the second, a nonprofit institution (in this case, the MITRE Corporation) was not found to be necessary to catalyze a research relationship between the university and a traditional energy-related industry. The MIT Polymer Processing Center was more successful. After five years of programmed declining NSF support, offset by increasing industrial contributions, it is now completely supported by industry and has developed a strong and durable operating mode. The research function is performed primarily by participating graduate students supervised by the Center director. Industry interactions have been focused on regularly scheduled Technical Review Meetings attended by thirty to forty people. Approximately half of these are MIT program staff personnel and the remainder are representatives of the industrial participants. Considerable interaction takes place between the program staff and representatives from the twelve companies that now participate in the Center.

There is no apparent difficulty with patent policy interfering with publication practices, nor any evidence that industrial cooperation is presenting antitrust problems. Rather, these questions appear to have been resolved at any early stage and do not interfere with the operation of the Center. The MIT Polymer Processing Center is a successful example of the Cooperative Research Center experiment spawned by the Federal government and now entirely self-supporting. It is an applied research enterprise, though it has some basic research and application components. It functions with relatively little direct industrial involvement and yet attracts considerable industrial support. About a dozen similar programs in other research areas currently are being funded by NSF.

Industrial-University Cooperative Research Projects are also funded by the National Science Foundation. A research

project is proposed jointly by a university and an industrial researcher, and subjected to the same review process as any individual project grant proposal for research support from the Foundation. The joint proposal is sent out for peer review and evaluated in the same way as any regular unsolicited proposal.

A central pool of resources is dedicated to this program and available to the research directorates within the Foundation. Any tendency for a program officer to recommend a joint university-industry project for funding, should its ratings in the review process fall below other funded regular proposals, is partially offset by the requirement that the program officer must provide a proportion of the funding. Industry is reimbursed for a portion of their cost, the scale ranging from 90% for small companies to 25% for the largest corporation. The latter figure is rather small. It may be insufficient to make such programs worthwhile to industry, given the amount of planning, negotiations, and paperwork such arrangements require. This is a weakness of such programs because large companies possess the largest number of excellent researchers who can work with university researchers most effectively.

This form of funding leaves the selection of the research problem up to the researchers, and clearly requires a close research relationship between university and industrial personnel. Many of these projects have developed out of prior university researcher-industry consulting relationships.

The Cooperative Automotive Research Program (CARP) is expected to be jointly funded by government and industry for basic research related to automotive technology. There are five domestic automobile manufacturers involved, with a range of universities, research institutes, and federal laboratories cooperating with industrial research laboratories. Personnel exchanges between industrial and university laboratories are encouraged. Wide and open dissemination of program results to all interested parties is likewise encouraged, subject to appropriate copyright and patent protection. A preliminary framework has been constructed, with a government funding level projected at a $6 million outlay and a $12 million obligation for 1981. It is intended that funding will increase substantially over the ensuing four years. This funding is to be matched by increases in basic research expenditures from each participating automotive company, in proportion to its recent proportion of motor vehicle sales. The research projects are intended to be performed primarily within universities, though it is expected that a portion of the industrial funds will be spent within their own research activities. Each of the participants will independently select the areas of research they intend to support, and the specific research group chosen to carry it out. A wide spectrum of activity will be covered and is intended to involve a variety of basic researchers in universities. This particular program has an Oversight Committee to ensure that the funded projects are of high quality and of a basic research character.

The patent issue does not seem to be a constraining factor. When contracts are let to universities by at least one of the industrial participants, title is intended to remain with the university, and only a non-revokable license is required.

It remains to be seen how well the CARP program will work. Preliminary meetings between university and industrial researchers have defined the areas of research. The university researchers see CARP as a means for contributing to the technology base needed by the automobile manufacturing companies, and appear to be eager to participate. The automobile industry sees CARP as an opportunity to add a substantial amount of basic research funding and intellectual resources to their technological base, and to train students in areas relevant to their research needs. The success or failure of this experiment must ultimately be measured in terms of how relevant the results of the program will be in fostering innovation in the automobile industry.

5. *Government incentives for industry financial support* of research programs in universities have potential utility as a major stimulus for cooperation. These incentives may take different forms and can be tailored for specific purposes. An example of such an incentive can be found in the proposed Research Revitalization Act of 1980 (HR 6632) which would grant a tax credit for contributions by private firms for qualified research expenses incurred by any institution of higher education. Qualified research expenses are defined in Section 174 of the Internal Revenue Code. These contributions could be made to a university department or to a principal investigator who is performing research in an area of interest to the company. Maximum industrial advantage from this investment would probably result if an industry scientist cooperated directly with the university researcher in the research program supported by the company. If such collaboration was not feasible, contact between the university researcher and a representative of the supporting industry who was familiar with the transfer of research results into the innovation process might serve to enhance the flow of information.

There is no advance measurement as to how much incentive such tax credits will create. To have an important impact, the tax credit must be of sufficient magnitude. The 46% tax rate paid by companies on taxable income in excess of $100,000 means that a tax credit of less than 10% would be so small to an individual company that it would be unlikely to act as a stimulating force. The proposed Research Revitalization Act of 1980 would provide

a tax credit of 25% for the contributions of a company for research performed by an institution of higher learning. The 25% credit would be in addition to the tax deduction for research and development expense as allowed by Section 174 of the Internal Revenue Code. At a marginal tax rate of 46%, the after-tax cost of a dollar of qualified research after the credit of the proposed Research Revitalization Act would be 29 cents, rather than the present 54 cents. This would nearly halve the cost to industry of supporting university research.

Only cash contributions that industry provides toward the support of university research qualify for the tax credit under the proposed HR 6632. In view of the current high price of modern sophisticated research equipment, provision should be made to allow tax credits for contributions of research equipment to universities by industry. This would serve two purposes: updating aging facilities of the university and providing an incentive for industry to purchase and use state-of-the-art equipment in their cooperative research projects with universities.[3]

There are problems with this application of tax credits as well. A tax credit for industry-supported research in the university requires that the support not be channeled into product development or production testing for the industry. It is this danger which leads the Commission to support limitation of tax credits only to contributions for research. The university bears a major portion of the burden for ensuring that contributions from industry go only to research programs, and not to disguised testing, development, or production activities.

Once granted by industry, the administration of funds by the university should remove the possibility that the monies could be used as a subterfuge for augmenting faculty remuneration for a normal consulting relationship on proprietary matters. Most universities do not permit payment to faculty in excess of full academic year salary from university administered funds.

Compelling questions concerning tax credits underlie the estimation of their benefits and costs to the government and the national research effort. Models of the costs to the government at various levels of industrial participation should not be difficult to construct. More difficult is the estimate of actual industrial participation. Thus, as pointed out by Dr. W. Baer[7] in a report to the National Science Foundation, there is little analysis to respond to three important questions: First, how much additional corporate research and development funds would flow to universities? Second, would the funds substitute for in-house industrial research and development? Third, would the total national research effort be affected? Even if confident projections were available, it would be difficult to assess the success or failure of such programs. Nevertheless, the reinforcing character of tax credits for university-industry research relationships, their relative administrative simplicity, and their attractiveness for both partners, combine to make this approach worth applying.

6. *Part-time employment for students in industry* has been established in a number of very successful cooperative programs of industry and universities that permit students the benefits of exposure to the industrial environment and earnings while pursuing their educations. This broadens the base of trained scientific and technical personnel in the country, and also provides opportunities for improving mutual understanding between universities and industry.

Conclusions

In light of the state of research and innovation in the United States, and considering the variety of needs and philosophies that guide the actions of universities, industry, and the government, the Commission has concluded that joint research relationships among the three types of institutions are beneficial and should be encouraged. More specifically, we offer the following conclusions:

1. The ultimate result of any form of university-industry research relationship must be better products and services useful to the public.

"Innovation" is the term most often used to describe a continuing flow of more useful products and service to meet public needs. Research is an essential component of the innovation process. Basic research may be the most important because it begins with seminal questions and a broad spectrum of possible explanations. To the extent that universities and technology-oriented corporations find ways to interact more effectively on basic scientific research, the usefulness of basic research information will also increase. This conclusion does not mean diversion of university researchers by industry. Rather, it implies mutual recognition of the value of applicable ideas or the feedback which often comes from application of relevant basic ideas.

2. Universities house the greater volume of basic research activity and are likely to continue to do so.

The size of the basic research effort in universities is much larger than that of industry. As one moves along the innovation process toward applied research, the industrial fraction substantially increases and industrial expenditures for development dwarf those of the universities. Statistics clearly demonstrate the primacy of the university in terms of expenditures for basic research (see Figure 2 on page 6).

The vast majority of university basic research resources derive from the Federal government, while industry supports directly three-quarters of its own basic research expenditures. The remainder is paid for by the Federal government. These figures mean that industry has relatively little influence on the university basic research agenda and that the Federal government has little influence on industrial basic research. A corollary is that industrial research and university basic research are largely isolated from each other.

3. Research relationships between industry and universities can strengthen the innovation process and improve the vigor of research within the universities.

Both the universities and industry can benefit from a closer research relationship if such a relationship is built upon the respective strengths and needs of each of the parties. *Basic research* is a particularly fruitful area to explore, since it is an area of strength in the university and represents an important industrial need. In recent years, industry has emphasized shorter term and more "defensive" research at the expense of fundamental or basic research. The universities could strengthen the front end of the innovation process and also assist industry to isolate the relevant discoveries from the overwhelming volume of research results that are published.

Industry could provide a sizable source of stable funding for the universities in contrast to the almost exclusive Federal government funding of current basic research programs. Through close interaction with industry, universities may better be able to make discoveries of potential importance for meeting public needs. Greater interaction between the university and industry could further the innovation process by reducing the time between research findings and their practical applications through applied research and development.

Joint university-industry cooperative research relationships should allow the results of basic research to be integrated into the innovation process. Information transferred in this manner between the researcher and others in the innovation process can enrich the entire enterprise.

The integrity of each of the participants must be preserved in the course of this interaction. In so doing, an opportunity is provided for the university researcher to understand the innovation process, without interference with the university research environment. This understanding, and the satisfaction of contributing to innovation, adds to the vigor of university research.

4. A close working relationship between the university researcher and the industrial counterpart is an imperative for a strong university-industry cooperative research program.

A working level research relationship between a university investigator and a peer from industry is the most successful mechanism to ensure that high quality research is incorporated into the innovation process. No single

structure can be identified as the model for a successful university-industry research relationship. Each connection must be structured in recognition of the respective strengths and needs of the particular parties involved. An element common to all should, however, be a close *working* relationship among university and industry scientists.

In addition, the choice of research subject should be left to the individual university and industry researchers. Existing cooperative programs reinforce these as a vital ingredient for success.

5. University-industry research relationships can contribute significantly to university research and instructional resources.

Research relationships with industry, whether through grants or direct contracts, can contribute to the vitality of the university research instruction and research program. The opportunity to contribute to the industrial technological base can be a driving force toward more vital research. New ideas for research may spring from attention to industrial problems, and the associated feeling of contribution to the development process can be a very stimulating experience. This can have a positive influence on the research programs of faculty members, broadening their horizons as well as those of their students.

The contact with industrial problems can make research more relevant for the faculty and students. This contact also can encourage the student to pursue industrial professions. Industry can then attract students of the highest quality in order to meet its research needs most effectively.

Income from patents and licenses can add to the university resources for research and instruction. Universities now lack a source of funds for new programs which require expensive equipment. Further, funds for new investigators, and for maintaining faculty between research grants, are hard to obtain. The return from proprietary licenses could provide the university with opportunities in all these areas. An example of this type of income and the excellent projects it can support can be found in the Wisconsin Alumni Research Foundation (WARF) program at the University of Wisconsin. WARF activities include direct research support of faculty, capital construction, permanent equipment, fellowships, and research grants for young faculty. Highly significant new research programs have been funded through WARF, while ongoing projects also have profited when federal funding was interrupted or fell short of needs.

6. Equitable financial rewards should accrue to industry and to universities from explicit research relationships.

Risks are inherent both in selecting the right questions for which to find answers and in finding the most effective paths to the answers. This requires that appropriate financial rewards through the exercise of proprietary rights to inventions be maintained.

The days of "big science" are here and likely will continue. Large commitments in time, personnel, and financing are required. Without some potential proprietary rewards, the immense costs of industrial development efforts emanating from basic research are not likely to be recouped.

Making a profit is a major objective of industry. It cannot afford to participate in cooperative research unless it expects to profit in some manner. One way to provide such a profit potential is by allowing a company participant to obtain exclusive patent rights to the research results. Cooperative research relationships imply that the return to a company as a consequence of commercialization of research results will be shared by the participating university.

7. Hazards to university academic freedom from university-industry research relationships are manageable.

Experience has proven that the individual researcher can continue his or her investigations unfettered and without undue influence under the aegis of a collaborative research program with industry. Careful advance planning with respect to publication rights, including patent application provisions, with good legal advice arranged by institutional counsel, can protect the university research environment. In general, industry wishes the continuation of free exploration of ideas within the university. It appears to be possible to plan a program of high quality university-industry cooperative research fully consistent with the academic environment.

8. Universities, in seeking opportunities for cooperative research with industry, must exercise care to avoid subversion of proper university purposes.

Universities which take initiative in seeking out individual industrial concerns to develop joint research programs in areas of mutual interest must do so with caution. The attractiveness of financial support from industry could lead researchers and administrators into arrangements which would subvert the research and instructional roles of the university. To the extent that the relationship is more of an applied or development

character, this danger increases. Universities generally know little about managing development or production facilities. They should remain with programs which contribute to the instructional environment and not venture into activities beyond their scope or capability.

9. Government can encourage and support the university-industry research relationship by becoming a facilitator rather than an ongoing participant in direction or management.

The government can support university-industry cooperative research programs through tax incentives and removal of unnecessary barriers to innovation. It also can play a role as a catalyst in creation of cooperative university-industry research programs by bringing the parties together, helping construct a framework for action, and providing direct financial support or seed money for a limited time.

10. The less basic the research, the more difficult becomes the determination of whether the use of public funds for university-industry research relationships is proper.

Public monies for cooperative university-industry research should not be used for industrial product development programs. The determination of whether this is occurring becomes more difficult and unsure, the more the research relationship contains activities of an applied or development character. Open publication of the results of the research relationship is usually sufficient to ensure that the research is available to the general public and not a part of an industrial production program. As joint research programs become more applied in nature, the objectives of the university and industry also are more likely to conflict in areas such as publication rights. These considerations all argue for the university-industry research relationship to be established toward the more basic research areas.

11. The public must be informed of the nature and rationale of specific university-industry research relationships.

There is great sensitivity on the part of some faculty and students and many members of the general public over the character of the cooperation between industry and the university. The concern is directed at possible subversion of university independence in the choice of its research and instructional programs, as well as possible misuse of public monies for the support of private purposes (see Conclusions 8 and 10). It is essential that research relationships between industry and universities be made public, and that the rationale for such relationships be made clear. Failure to do so many eventually result in charges that these relationships compromise the purposes of the university, result in the loss of its independence, and possibly lead to diversion of its efforts and resources.

12. Misunderstanding and mistrust exist among members of industry, university students and faculty, and the general public, impeding cooperative research relationships between industry and universities. A new mechanism for discussion and resolution of the issues is needed.

There is no easy way that an atmosphere of trust and confidence can be established between industry and the university. The public has serious reservations about the use of public funds for the support of research to be used for industrial purposes. Without a congenial public attitude, the development of widespread cooperative research relationships between industry and universities will be a difficult and slow process.

A previous report of the Commission, *Accountability: Restoring the Quality of the Partnership*, suggested the formation of a "... new, independent Forum whose purpose would be to watch over the government-university research relationship and to guide its evolution."[8] The Commission suggests that this might be an effective vehicle for helping to alleviate constraints which currently preclude a vigorous university-industry-government cooperative research relationship. Membership of the Forum should include individuals who are familiar with university-industry research relationships from the university community, industry, and government. Public discussion of the issues involved in research cooperation between industry and universities may prove in the long run to be the most effective way to bring a healthy and productive research relationship into being.

Recommendations

1. The Commission recommends that research universities and industries explore effective cooperative research relationships which:

- ***a. Are designed around important scientific areas of mutual interest, individually tailored to the characteristics of each participant—emphasizing investigator-to-investigator interaction.***
- ***b. Possess clearly stated objectives that preserve each partner's purposes and policies, recognizing that the often subtle differences fundamental to each partner must be understood and respected.***
- ***c. Allow the individual researchers from both university and industry to determine the specific choice of subjects to be investigated. Permit each partner's participants to share in any phase of the projects appropriate to their skills.***
- ***d. Provide for financial reward to industry and to the university for assuming the risks of bringing highly uncertain scientific and technological programs to fruition and usefulness;***
- ***e. Provide opportunities for demonstrating research performance and ethical qualities that will develop mutual respect for doing good science; and***
- ***f. Develop a commitment for long-range support of research, recognizing that meaningful research results are rarely achieved in short periods of time.***

Universities and technologically oriented corporations function in different environments. There are many societal needs with dimensions exceeding the capabilities or scope of either university or industry—issues such as energy, the environment, food and nutrition, materials, transportion, and housing.

The Commission recommends exploration for new ways for these two segments of society to produce synergistic results. If properly harnessed, the intellectual resources of research universities and technology-oriented industry with their innovative capabilities could provide new levels of national prosperity.

A cooperative relationship between a university and a corporation for trivial matters is unwise. The rise of "big science" with its sophisticated and expensive requirements for facilities and instruments has pervaded almost every sector of basic science as well as applied research. Highly selected university-corporate partnerships with rapidly moving but long-term industrial financial commitments and developmental capabilities can improve, rather than hinder, opportunities for university researchers to pursue basic science.

2. The Commission recommends that companies within a sector of industry review their research needs and explore the possibility of combining their resources for the support of a coordinated program of cooperative research with universities.

Many industries are faced with common areas of interest and concern that would lend themselves to cooperative research. Research requires a critical mass of people and equipment in order to be effective. Individual companies often cannot justify setting up their own programs. In such cases, a cooperative program would appear to be a worthwhile alternative to consider. In view of the highly competitive nature of most American industries, it would be most fruitful to establish such programs in areas of basic research to minimize concerns such as proprietary rights.

The federal government could play a role by providing seed money for creating such relationships. Federal government financial participation, however, should be limited to the formative stages and be supplanted by industrial funding as soon as possible. The Department of Justice should review and clarify its interpretations of antitrust law pertinent to such relationships.

3. The Commission recommends that the Federal government encourage the application of research results to product development by permitting universities to retain title to inventions developed under federally supported research.

Federal government agencies currently operate under a confusing and inconsistent array of statutes and policies regarding rights and title to inventions arising out of federally supported research in universities. Some of these require that the government retain title; others permit an agency to waive title only after considerable paperwork. Research performers are often either completely denied rights to their inventions, or cannot be sure

of what rights they will receive. Federal regulations make it difficult to obtain an exclusive license on a government owned invention, destroying the profit potential necessary to encourage investment and development.

The Commission recommends that title to inventions arising out of federally supported research be left with the university. This would encourage industry to expand its investment in university cooperative research in order to obtain rights to inventions. The climate for university licensing would be improved, and industrial concerns about government claims under related research would be eliminated. As an example, a substantial portion of all medical research is done at nonprofit institutions. Because of the importance of patent rights to pharmaceutical and related industries, such a policy could be critical to the development of new drugs and medical devices and procedures at universities.

Certain "march-in" provisions would remain with the government, sufficient to guarantee that if the university did not take action with the invention, title would revert to the government.

This suggestion is a departure from current practice because no royalties or other forms of recoupment are to be paid to the Federal government by the commercializing company. The Commission believes this is a reasonable arrangement. The government and the public it represents need not receive royalties to profit from commercialization of an invention because through income taxes the government automatically shares in any extra profits that may result from an invention. Set against the benefits that might be gained through recoupment are inevitable administrative costs. These include negotiation of equitable arrangements, reports, and audits. Their costs are likely to exceed any amount that would accrue to the government.

4. The Commission recommends that the Federal government provide financial incentives to initiate and maintain closer research ties between industry and universities. Tax policy provides an effective vehicle for such incentives.

Lack of investment in university research by industry in part is due to the length of time required to see a return and the uncertainty of such a high risk investment. Without some financial inducement, industrial support of university research will remain small.

Tax incentives have long been used to promote desirable national objectives. Such incentives should be applied to encourage industrial support of research at universities. In order for such a policy to have a significant impact, it should:

a. Provide tax credits on the order of 25% for industry contributions to research carried out at universities;

b. Provide liberal carry-over provisions (application of credit to prior or later year earnings) to ensure that these benefits are provided to firms with highly variable earnings;

c. Develop appropriate means to encourage cooperative research programs between small companies and universities;

d. Allow credits to be applicable only to programs with a minimum three-year commitment from industry to ensure funding stability; and

e. Allow a value for research equipment contributed to universities by industry to qualify for a tax credit.

5. The Commission recommends continued direct university-industry cooperative research relationships based on models which have proven effective. One such example is the National Science Foundation Industrial-University Cooperative Research Project Program.

The program cited in this recommendation has proven to be an effective vehicle for university-industry cooperative research. It enables the principal investigators to choose freely their areas of concentration, subject to the scrutiny of the peer review system. The Commission makes this recommendation on the assumption that the calibre of research supported under such arrangements is comparable to that being carried out under individual project grants.

Thought should be given to mechanisms for stimulating industrial interest. This may take the form of greater financial inducements for industrial participants. The example of the National Science Foundation Industrial-University Cooperative Research Project Program is one in which larger participating companies are reimbursed for only a small fraction of their actual costs. Yet these companies are most often the ones which possess highly qualified scientists. A low reimbursement can make such potential participants question whether it is worth the trouble to pursue cooperative research arrangements. A substantial increase in percentage reimbursement would be a small price to pay for the productive research relationship that can result.

6. The Commission recommends that university researchers be encouraged to contribute to the research knowledge base required for regulatory policy, particularly in the biological/environmental area.

In many respects, the current status of basic scientific information appropriate for regulatory decision is confused. Industrial research for the purpose of generating scientific data for regulation requirements is suspect among regulatory agencies. Adversarial relationships between government agencies and industries exist in which the intention and credibility of both are in contention. The complexity of the issues is so great that the best minds from all informed segments are required to set a solid scientific base for subsequent government regulatory policy decisions.

In general, the university community has maintained high credibility on scientific matters it has addressed. However, until quite recently, it has played only a minor role in generating scientific data relevant for regulatory agency decisions. The Commission believes the university community could develop an important role in the process for developing sound science useful in setting regulations. The Commission recommends the removal of unnecessary impediments to research interactions in the most effective combinations. Joint definition, planning, and execution of research work among the three groups mentioned above on topics of regulatory relevance lead to improved credibility. At the same time, progress can occur in minimizing inconsistency of regulation, in reducing the delay in adopting innovation, and in reducing elements of inflexibility.

The Commission recognizes dangers to the university in becoming involved in scientific questions of great social import, but the alternative is what we have now—considerable confusion.

7. The Commission recommends that universities examine their administrative structures and policies relevant to cooperative research arrangements with industry. Such research arrangements should facilitate cooperation, while protecting the academic research environment. Universities also should examine their patent policies and be sure they have staff capable of identifying and pursuing patent opportunities.

If cooperative programs between university and industrial researchers are to flourish and expand, some form of guidelines must be established for a university campus. Guidelines may differ from one institution to another because of the diversity of academic institutions. The universities should develop campus policies regarding cooperative research with industry, involving its faculty and students. This policy should be made known to all researchers on the campus and should encourage university staff to initiate such relationships. Each university might want to identify industries, usually in the nearby geographical region, with a mutual interest in developing research relationships. For emphasis, it is worth reiterating that such arrangements may not be practicable for all universities. Some may not want to make the adjustments necessary to construct cooperative research arrangements with industry. Industries and universities are diverse, and these programs may not be suitable for all.

Another area demanding university attention is patent opportunities. Too often there is little or no contact between the university researcher and the administrative officer charged with patent development. This lack of communication can prove very costly.[9]

The universities should review their patent policies in the light of cooperative research projects and determine if their available legal staff resources are sufficient to meet university needs. Communication with faculty is essential to inform them of patent opportunities and to enable the university legal and administrative staffs charged with patent responsibilities to do their job.

8. The Commission recommends that universities and industry take steps toward removing the misunderstanding and mistrust between them.

University campuses have been the scene of unrest and outrage over alleged complicity of university administrations, faculty, and some students in untoward relationships with the national security community and military-related industries. Protests over alleged university expenditures of public funds for the direct support of agribusiness is another example. The intensity of these protests seems to have faded, but the underlying mistrust of university and business motives remains.

These concerns must be faced, and every effort should be made to facilitate understanding of the character of cooperative research programs within both industry and universities. Student participation in the projects, a campus review board for proposed projects, and seminars for industrial researchers and administrators, are three examples of steps which could alleviate this problem.

Great sensitivity to this important issue must be shown by all the participants in a cooperative research program, along with patience when explaining the character of the relationship and the contents of the research to interested parties.

9. The Commission recommends that universities and industry inform the public of the rationale for their participation in cooperative research programs. They must make public the developing relationships and the outcome of cooperative research programs.

The public is concerned over possible unwarranted intrusions by private business into the academic environment. As a consequence, cooperative programs between industry and universities can arouse suspicion. It is in the interest and is the responsibility of both parties to inform the public of the rationale for cooperative research and to keep the public informed of the character and content of developing relationships.

Academic institutions could involve public members in their committees to develop policy toward cooperative research programs with industry. They could publicize the general character of those cooperative projects they hope to see established.

Both partners must recognize that it may not be possible to satisfy all concerns over cooperative research relationships. Attempts to inform will certainly be misconstrued by some individuals or organizations. Nevertheless, an honest attempt to keep the public fully informed is an essential part of any cooperative research program between industry and universities. The strength of the university lies in its openness of communication. The same characteristic should mark its programs of cooperative research with industry.

Appendix I: References

1. Advisory Committee on Industrial Innovation. *Domestic Policy Review*, Final Report. (Washington, D.C.: U.S. Department of Commerce, 1979), p. 205.
2. National Science Foundation. *National Patterns of R & D Resources, 1953-1978-79.* (NSF 78-313), Table B-2.
3. Lyon, R. E., Jr. "A Bridge Reconnecting Academia and Industry Through Basic Research." IN *Proceedings of the George Washington University Science Policy Seminar Series, 1979-80.* (Philadelphia, Pennsylvania: Franklin Institute Press) *to be published, Fall, 1980.*
4. National Commission on Research. *Funding Mechanisms: Balancing Objectives and Resources in University Research.* (Washington, D.C.: National Commission on Research, May 1980).
5. Pruitt, M. E., ed. *First Midland Conference on Advances in Chemical Science and Technology, October 15-17, 1979.* Dow Chemical Company, 1980, p. 183.
6. Lucchesi, Peter J. IN: M. E. Pruitt, ed. *First Midland Conference on Advances in Chemical Science and Technology, October 15-17, 1979.* Dow Chemical Company, p. 178.
7. Baer, Walter S. "Strengthening University-Industry Interactions." Prepared for the National Science Foundation, January 1980.
8. National Commission on Research. *Accountability: Restoring the Quality of the Partnership.* (Washington, D.C.: National Commission on Research, March 1980), p. 27.
9. See, for example, *Science*, 208,693, May 16, 1980.

Appendix II: Bibliography

Advisory Committee on Industrial Innovation. *Domestic Policy Review*. Final Report. (Washington, D.C.: U.S. Department of Commerce, 1979).

Baer, Walter S. "University-Industry Interactions in Civil Sector R & D." Rand Corporation, Santa Monica, California, P-5724, October 1976.

Baer , Walter S. "Universities and Other R & D Performers." IN: B. L. R. Smith and J. J. Karlesky, eds. *The State of Academic Science*, II, Background Papers. (New Rochelle, New York: Change Magazine Press, 1978).

Baer, Walter S. "Strengthening University-Industry Interactions." Prepared for the National Science Foundation, January 1980.

Bugliarello, George. "The Problem of Industry-University Interaction." IN: Fred Landis, ed. *Proceedings, Engineering and Science Research for Industrial Development*. (Washington, D.C.: National Science Foundation, October 1977).

David, Edward E., Jr. "Science Futures: The Industrial Connection." *Science*, 203, 837-40, March 2, 1979.

David, Edward E., Jr. "General Sarnoff and Generic Research." *Science*, 207, 719, February 15, 1980.

Energy Advisory Committee, Association of American Universities. *University Contributions to the National Energy Program: New Knowledge, New Talent, New Interpretation*. Unpublished report, September 21, 1979.

Evenson, Robert E.; Waggoner, Paul E.; and Ruttan, Vernon W. "Economic Benefits from Research: An Example from Agriculture." *Science*, 205, 1101-1107, September 14, 1979.

Fred, E. B. *The Role of the Wisconsin Alumni Research Foundation in the Support of Research at the University of Wisconsin*. (Madison, Wisconsin: Wisconsin Alumni Research Foundation, March 1973).

Hess, Charles E. "Agricultural Research: What is Going On? Who Benefits? Who Pays?" Presentation before the Seventh Annual Almond Research Conference, Sacramento, California, December 11, 1979.

Lyon, R. E., Jr. "A Bridge Reconnecting Academia and Industry Through Basic Research. IN *Proceedings of the George Washington University Science Policy Seminar Series, 1979-80*. (Philadelphia, Pennsylvania: Franklin Institute Press) *to be published, Fall, 1980*.

National Commission on Research. *Accountability: Restoring the Quality of the Partnership*. (Washington, D.C.: National Commission on Research, March 1980).

National Commission on Research. *Funding Mechanisms: Balancing Objectives and Resources in University Research*. (Washington, D.C.: National Commission on Research, May 1980).

National Science Board, National Science Foundation. *Science Indicators 1978*. (Washington, D.C.: U.S. Government Printing Office, 1979).

National Science Foundation. *National Patterns of R & D Resources, 1953-1978-79*. (NSF 78-313).

National Science Foundation. *Academic Science R & D Funds, FY 78*. (NSF 79-320).

Office of the White House Press Secretary. "Fact Sheet: The President's Industrial Innovation Initiatives." Washington, D.C., October 31, 1979.

Prager, Denis J. and Omenn, Gilbert S. "Research, Innovation, and University-Industry Linkages." *Science*, 207, 379-84, January 25, 1980.

Pruitt, M. E., ed. *First Midland Conference on Advances in Chemical Science and Technology, October 15-17, 1979*. Dow Chemical Company, 1980.

R & D Economic Studies Section, Division of Science Resources Studies. "National R & D Spending Expected to Reach $67 Billion in 1981." *Highlights* (NSF 80-310), May 23, 1980.

Research and Policy Committee. *Stimulating Technological Progress*. (New York: Committee for Economic Development, January 1980).

Science, 208, 693, May 16, 1980.

Smith, Bruce L. R. and Karlesky, Joseph J. *The State of Academic Science, The Universities in the Nation's Research Effort*, I. (New Rochelle, New York: Change Magazine Press, 1977).

Udell, Gerald G.; Baker, Ken; and Colton, Robert M. "The Innovation Center Program." *Research Management*, July 1979, pp. 32-38.

Appendix III: Sources

The Commission is indebted to the many persons who have provided information and advice, and it wishes to acknowledge its appreciation for their efforts. Invited expert witnesses have testified on the issues within the Commission's purview at its monthly meetings; open hearings have been held on five university campuses; subcommittees have met with individuals and groups from the Federal government and industry; and members and staff have attended or made presentations at meetings and hearings convened by educational and industrial associations, government agencies, and Congress.

Witnesses. The following individuals presented views and gave assistance in the development of this document. The Commission wishes to emphasize that the views in this document are its own and not necessarily those of the listed individuals.

Walter S. Baer, Rand Corporation
Albert A. Barber, University of California, Los Angeles
Fred Betts, National Science Foundation
Howard Bremer, University of Wisconsin, Madison
Honorable George E. Brown, Jr., U.S. Representative from California
John Chester, National Science Foundation
W. G. Clark, University of California, Los Angeles
Camden Coberly, University of Wisconsin, Madison
Belle Cole, University of California
Tom Collins, University of California, Los Angeles
Robert Colton, National Science Foundation
W. Dale Compton, Ford Motor Company
Jack Crowley, Association of American Universities
Joel Davidow, Department of Justice
Roger G. Ditzel, University of California
Dixon Fiske, Exxon Research and Engineering Company
George Gamota, Department of Defense
William Gibb, U.S. Senate Committee on Commerce, Science and Transportation
Howard Gobstein, General Accounting Office
Barry Gruenberg, General Accounting Office
Fred Haynes, Department of Commerce
R. E. Hefner, Dow Chemical
Charles E. Hess, University of California, Davis
Charles H. Herz, National Science Foundation
Thomas M. Hinkes, Wisconsin Alumni Research Foundation
William Kays, Stanford University
Susan Croce Kelly, Monsanto Company
Carlos Kruytbosh, National Science Foundation
Ralph Landau, Halcon International
Norman J. Latker, Small Business Administration
E. L. MacCordy, Washington University
Kenneth McLennan, Committee for Economic Development
Richard A. Meserve, Office of Science and Technology Policy
Walter Meyerhof, Stanford University
Michael W. Moureau, National Science Foundation
Gilbert S. Omenn, Office of Science and Technology Policy
George Pake, Xerox Corporation
Frank Press, Office of Science and Technology Policy

M. E. Pruitt, Dow Chemical
Simon Ramo, TRW, Inc.
Steven R. Reznek, Environmental Protection Agency
David S. Saxon, University of California
Philip M. Smith, Office of Science and Technology Policy
A. P. Speiser, Brown, Boveri and Company, Ltd.
Richard Tropp, Environmental Protection Agency
Barney Wander, Monsanto Company
Carol Warner, Legislative Assistant to Honorable Charles A. Vanik, U.S. Representative from Ohio
Gunther O. Wilhelm, Exxon Research and Engineering Company
David Wilson, University of California

Agency Liaison. These persons have been appointed by their agencies:

Salvatore Cianci, Alcohol, Drug Abuse, and Mental Health Administration
George P. Millburn, Department of Defense
Richard E. Stephens, Department of Energy
Osmund Fundingsland, General Accounting Office
Walton Francis, Department of Health, Education, and Welfare
James R. Lawson, National Aeronautics and Space Administration
William F. Raub, National Institutes of Health
Jack Sanderson, National Science Foundation
Eliot R. Cutler, Office of Management and Budget
Philip M. Smith, Office of Science and Technology Policy.

Open Hearings. Over seventy persons testified before the Commission during hearings at the national conference of the American Association for the Advancement of Science and on the campuses of the University of Alabama, Birmingham; California Institute of Technology; Stanford University; the University of Wisconsin, Madison; and the University of Utah with the Inter-Mountain University Research Association.